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NORTHEAST ELECTRONICS
Division of nt northern telecom
Airport Rd., Concord, N.H. 03301•(603) 224-6511•TELEX 94-3453

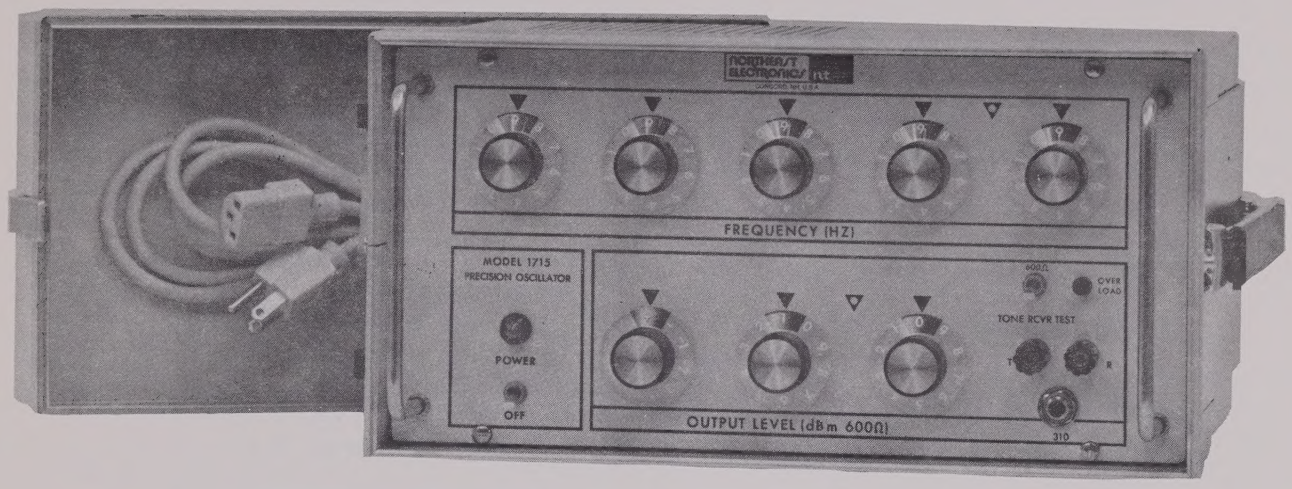
INSTRUCTION MANUAL

MODEL 1715

PRECISION OSCILLATOR

PRINTED IN U.S.A.

No. A1715-01-600 ISSUE 1 DATE AUG 1977



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SECTION 1

GENERAL DESCRIPTION

1.1 SCOPE

1.2 This manual provides operating and maintenance instructions for the Model 1715 Precision Oscillator identified by Northeast Electronics part number A1715-01-900. The manual provides sufficient technical information to operate, maintain, calibrate and repair the Precision Oscillator. The Precision Oscillator meets the requirements of Western Electric specification KS-21715.

1.3 APPLICATIONS

1.4 Although the Precision Oscillator is intended primarily for testing and adjusting TOUCH-TONE® receivers, it may be used for many other applications requiring precision frequencies between 100.0 Hz and 9999.9 Hz with a power range of +9.9 dBm to −39.9 dBm. For example it may be used to check and calibrate MF and R2 filters, completely eliminating the need for conventional audio oscillators and frequency counters.

1.5 A complete tone decoding system may be checked using two precision oscillators. This allows independent variation of the frequency of each output sinewave as well as the total output level and the difference in tone levels. Practically any communication system that uses tone selective signaling may be tested, including tone-actuated receivers and mobile communications equipment such as Amateur Radio and Citizens Band radio. For example, the Precision Oscillator may be used as a modulation source for AM or FM signal generators to simulate radio system transmitter signals.

1.6 An additional application of the Precision Oscillator, in conjunction with a Northeast Electronic's TTS 44 Transmission Test Set, involves frequency shift measurements on carrier channels. The Precision Oscillator may be used to generate a known, stable frequency and a TTS 44 may be used to measure the frequency shift.

1.7 FUNCTIONAL DESCRIPTION

1.8 The oscillator output frequency is selectable in 0.1 Hz increments from 100.0 Hz to 9,999.9 Hz. Output level may be varied from +9.9 dBm to −39.9 dBm in 0.1 dB increments. In addition to a specially calibrated output for use during TOUCH-TONE® receiver calibration, the oscillator provides a 600 ohm balanced output for general-purpose use. The oscillator is powered from a 115 Vac, 60 Hz source.

1.9 Frequency selection is made by using five, front-panel, 360° rotary switches. Each switch selects one digit of the output frequency and has the range 0 through 9.

1.10 The oscillator's two outputs are switch-selectable for use of either one, but not both, at the same time.

1.11 Amplitude selection is made by three front panel, rotary switches. The left-most switch selects the sign and first digit of the output level as follows: +0, −0, −1, −2, and −3. The other two switches select the second and third digits of the output power; each of these two switches has a range of 0 through 9. The output level selected is dBm into 600 ohms.

1.12 When the 600 ohm balanced output is chosen, the selector switches indicate the level supplied to a 600 ohm load. (If the load is something other than 600 ohms, the actual level differs from the selected value).

1.13 When the output for Tone Receiver testing is chosen, the level is exactly the same as the value selected on the front-panel switches, and is expressed in dB with respect to 0.7746 volt. This applies to all TOUCH-TONE® receiver impedances between 900 and 40,000 ohms at the test frequency.

1.14 Since the load driven by the tone receiver test output may be connected to frame ground or −48 V battery, the entire oscillator circuit is isolated from the ac supply ground (chassis ground).

1.15 Both oscillator output circuits are protected so that a short circuit causes no damage. In addition, the Tone Receiver test output controls a front panel OVERLOAD indicator lamp. The indicator lights if the output level is ever forced out of calibration by an excessive load.

1.16 Two internal adjustments are provided for calibrating the frequency and amplitude to agree with the oscillator front panel control indications. Amplitude calibration is made at a frequency of 1000 Hz for a 0 dBm level into a 600 ohm load. Frequency calibration is made at 9,999.9 Hz at room temperature. Two additional internal adjustments are provided to set the output level and impedance of the 600 ohm general purpose output.

1.17 PHYSICAL DESCRIPTION (FIGURE 1—1)

1.18 The Precision Oscillator is housed in a small, portable, case with a removeable front cover. A detachable ac power cord is stored inside the cover, and a carrying handle is provided on one side. With the cover removed for operation, all front panel controls are accessible. They are protected by two handle-type guards.

1.19 The oscillator weighs approximately 15 pounds, including the cover and accessories. Dimensions are 13" w x 12" d x 7" h with the cover removed.

1.20 Operator controls and indicators for frequency, power and application of ac power are located on the front panel. Four calibration adjustments are located internally. An output jack and tip/ring binding posts are located on the front of the case. The jack mates with a Western Electric Company 310 plug. The oscillator output appears between the tip and ring. The sleeve is not connected and is isolated from chassis ground. The rear panel contains a 1 ampere slo-blo fuse, a standard 3-prong ac receptacle, and a 115/230 Vac selector switch.

1.21 The oscillator contains four assemblies as follows:

1. DC Power Supply
2. BCD Switch Board
3. Digital Board
4. Analog Board

All assemblies are field replaceable.

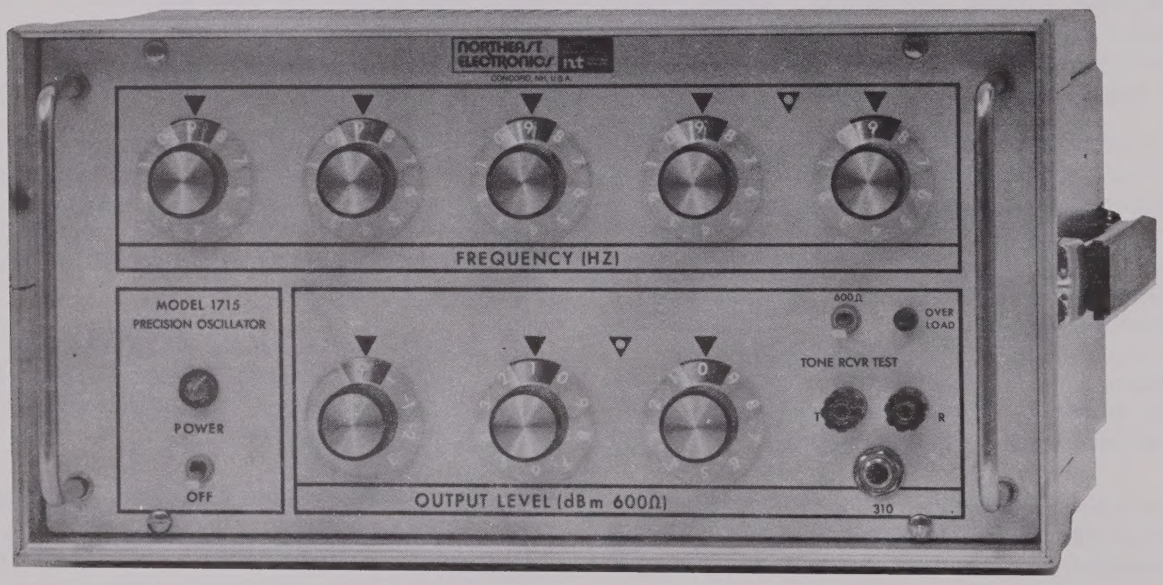

Figure 1—1. Precision Oscillator

SECTION 2

SPECIFICATIONS

2.1 Table 2—1 tabulates the electrical, mechanical, environmental and performance specifications for the Precision Oscillator.

Table 2—1. Specifications

ELECTRICAL SPECIFICATIONS	
Input Power:	105 to 125 Vac/210 to 230 Vac 57 to 63 Hz at 20 watts nominal.
DC Power Supplies (Internal):	+5 volts @ 1.0 A +15 volts @ 150 mA −15 volts @ 150 mA
Overload Protection:	1 A input ac fuse. Crowbar circuit protects +5-volt output.
MECHANICAL SPECIFICATIONS	
Weight:	15 pounds (6.8 kg)
Dimensions (without cover):	13″ w x 7″ h x 12″ d (33 cm x 17.8 cm x 30.5 cm)
Cover (contains 7′ power cord):	13″ w x 7″ h x 2″ d (33 cm x 17.8 cm x 5 cm)
Equipment Guards:	Two handle-type guards protect front panel.
ENVIRONMENTAL SPECIFICATIONS	
Storage Temperature:	−40°C to +75°C
Operating Temperature[1]:	0°C to +50°C
Relative Humidity:	10 to 95%
Mechanical Shock:	Per Bell Pub 41009.

[1]Overall temperature range. See Performance Specifications below for temperature vs. frequency range.

PERFORMANCE SPECIFICATIONS	
Selectable Outputs:	Tone Receiver Test (900 to 40,000 ohms termination); General Purpose (600 ohms termination)
Frequency Increments:	Adjustable between 100.0 Hz and 9,999.9 Hz in 0.1 Hz increments.
Frequency Accuracy:	±0.05 Hz (15°C to 35°C) ±0.1 Hz (0°C to 50°C)

Table 2—1. (Cont'd)

PERFORMANCE SPECIFICATIONS (Cont'd)

Frequency Drift:	Less then 0.05 Hz per 8 hours for frequencies below 1700 Hz after initial 5 minute warmup. Less then 0.01 percent per hour for frequencies above 1700 Hz.
Output Power Range:	+9.9 to −39.9 dBm in 0.1 dB steps for both outputs. Selected output power referenced to 600 ohm termination regardless of actual termination.
Output Power Accuracy	
Tone Receiver Test Output:	±0.1 dB (650 Hz to 1700 Hz @ +9.9 to −39.9 dBm) Output is short circuit proof. Provided with OVERLOAD detector and indicator.
General Purpose Output: (stability 0.05 dB per hour after 5 minute warm-up).	±0.5 dB (100 Hz to 200 Hz) ±0.2 dB (200 Hz to 9,999.9 Hz @ +9.9 to −39.9 dBm)
Output Impedance Drive Capability	
Tone Receiver Test Output:	900 to 40,000 ohms with output isolated from ac ground (chassis ground). DC blocked to 150 Vdc.
General Purpose Output:	600 ohms balanced transformer output DC blocked to 300 Vdc.
General Purpose Return Loss:	Greater than 30 dB (200 Hz to 9999.9 Hz)
General Purpose Output Longitudinal Balance:	80 dB at 60 Hz; 70 dB at 540 Hz; 50 dB at all other frequencies below 4000 Hz (Decreasing at 6 dB/octave above 4 kHz)
Long Term Stability:	One Year

HARMONIC DISTORTION PLUS NOISE

As measured on a distortion analyzer which eliminates only the fundamental tone.

FUNDAMENTAL FREQUENCY (f_o)	MEASUREMENT BANDWIDTH (3 dB points)	TOTAL DISTORTION PLUS NOISE
100 to 1100 Hz	30 Hz to 4000 Hz	≥50 dB down
1200 to 3000 Hz	30 Hz to 4 X f_o	≥50 dB down
>3000 Hz	30 Hz to 4 X f_o	≥40 dB down

Over output level range specified below for general purpose 600 ohm output and over the range of +9.9 to −29.9 dBm for the Tone Receiver Test output.

SECTION 3

INSTALLATION

3.1 The Precision Oscillator is a portable unit and requires no installation.

3.2 INITIAL INSPECTION

3.3 The unit is carefully inspected, both mechancially and electrically, before shipment. It should be free of defects and should be operating correctly when received. To confirm this, visually inspect the unit for signs of damage during transit. Notify the common carrier immediately if any damage is found.

3.4 POWER CONNECTIONS

3.5 The unit operates from 115 or 230 Vac external power. Power connections are made with a 7' detachable power cord connected to the rear panel as described in paragraph. 4.3.

3.6 SERVICE INFORMATION

3.7 Each instrument manufactured by Northeast Electronics is warranteed for a period of one year from date of delivery to the original purchaser. Complete warranty information is contained in the purchase order agreement under Terms and Conditions of Sale. Written authorization is required prior to the return of any equipment for factory repairs. Additional service information can be obtained by contacting Northeast Electronics, Customer Service Department, P.O. Box 649, Concord, New Hampshire, 03301, telephone number 603-224-6511.

SECTION 4

OPERATION

4.1 CONTROLS AND INDICATORS

4.2 Operator controls and indicators are illustrated in Figure 4—1 and described in Table 4—1.

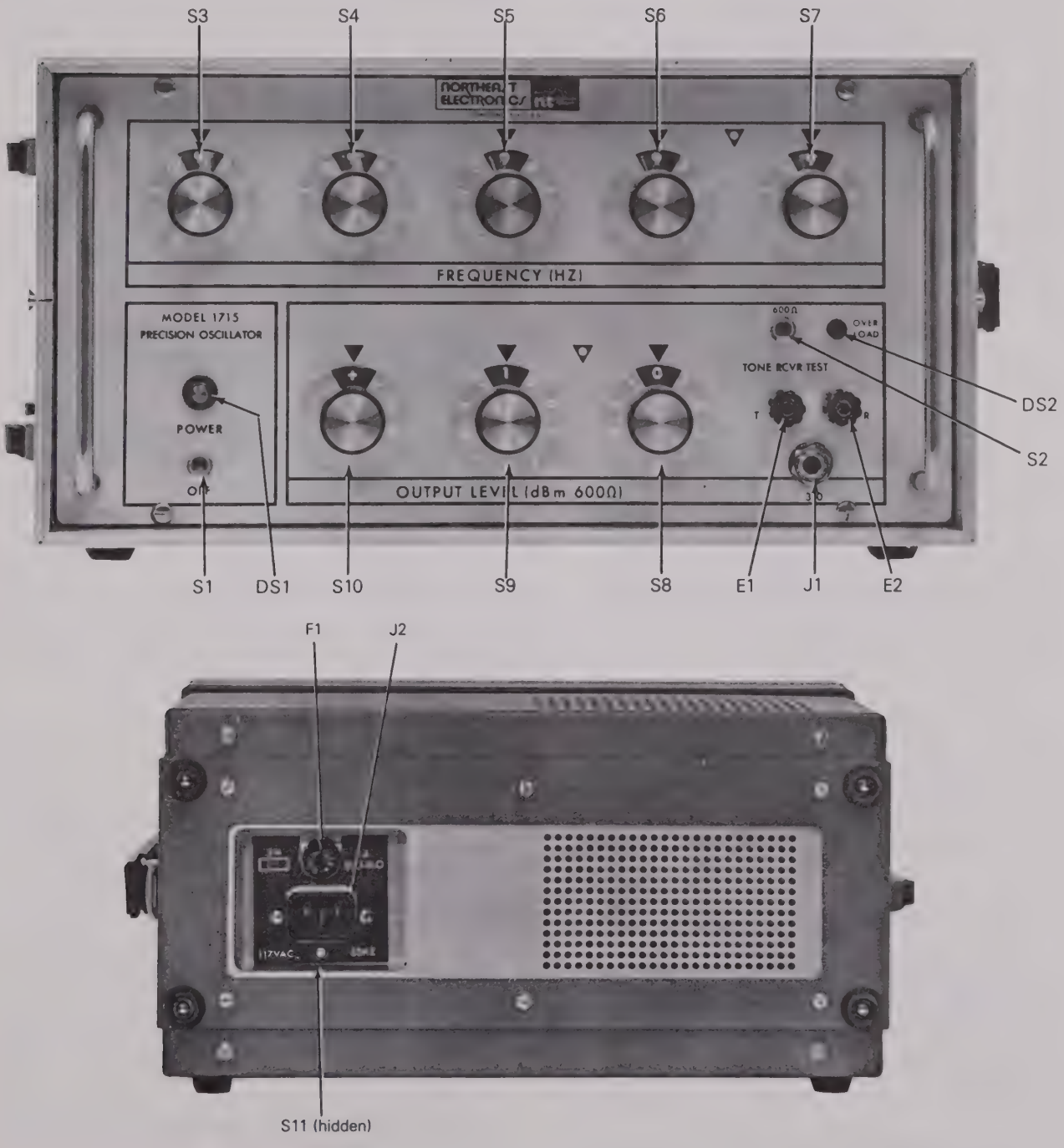

Figure 4—1. Controls and Indicators.

Table 4—1. Controls, Indicators, And Connectors

REF DESIG	CONTROL, INDICATOR OR CONNECTOR	FUNCTION
DS1	POWER, indicator lamp	Illuminates when power is applied.
DS2	OVERLOAD, LED indicator	Illuminates if an overload (short circuit or low impedance) occurs when using TONE RCVR test output.
E1 & E2	Binding posts (T, R)	Provide parallel tip and ring connections for 310 jack.
S1	POWER, toggle switch	Applies input ac power.
S2	600 Ω ,TONE RCVR TEST, toggle switch	Selects either 600 ohm balanced general-purpose output or TONE RCVR test output.
S3—S7	FREQUENCY (Hz), rotary switches	Five independent switches select output frequency from 100.0 Hz to 9,999.9 Hz in 0.1 Hz steps. All switches range from 0 to 9. Decimal point is located between tenths and units digits.
S8—S10	OUTPUT LEVEL, rotary switches	Three, independent switches provide selection of output amplitude from +9.9 to −39.9 dBm in 0.1 dB steps. Left most switch positions are −3, −2, −1, −0 and +0. Right two switches range from 0 to 9. Decimal point is located between tenths and units digits.
S11	115/220 VAC switch	Selects input power.
J1	OUTPUT jack (310 plug receptacle)	Provides output signal connection.
J2	AC power, 3-prong receptacle (rear)	Provides for connecting to ac power source.
F1	1 amp slo-blo (rear)	Protects ac input from overload.

4.3 TURN-ON PROCEDURE

1. Place oscillator within 7 cable feet of a 115 Vac power outlet.

2. Unlatch front cover and remove power cord from cover.

3. Set 115/230 Vac switch to appropriate position.

4. Ensure POWER switch is OFF and connect power cord between ac receptacle on rear of Precision Oscillator and power outlet.

5. Place POWER switch ON and observe that POWER lamp lights.

6. Set FREQUENCY and OUTPUT LEVEL switches as desired.

4.4 OPERATING INSTRUCTIONS

4.5 GENERAL-PURPOSE USE.

4.6 For use as a general-purpose precision oscillator, a test cord equipped with one 310 type plug and appropriate cord tips is required. The following procedure is typical and should be modified as required for the particular application.

1. Place TONE RCVR TEST/600 OHM switch to desired position.

2. Select desired frequency and output level using front panel switches.

3. Connect 310 type plug of test cord to the Precision Oscillator's 310 output jack.

4. Connect cord tips of test cord to device to be tested.

5. Place POWER switch ON and observe that POWER lamp lights.

6. Change FREQUENCY and OUTPUT LEVEL switches as necessary.

7. At the completion of the test, place POWER switch OFF and disconnect test cord.

NOTE

The oscillator can withstand a continuous overload when operating in the 600 OHM or TONE RECEIVER output modes; however, the OVERLOAD lamp is operational only in the TONE RECEIVER position of the output switch.

4.7 TOUCH-TONE® RECEIVER TESTING

4.8 Specific procedures for using the Precision Oscillator to test and adjust TOUCH-TONE® Receivers vary among different users and also depend upon the particular receiver and installation configuration. The procedure presented below is based on standard practices for testing and adjusting TOUCH-TONE® station test circuits. It is a generalized application of the standard practices and should be used as a guide only.

4.9 Generally, two types of tests are made, one to determine that the passband of the receiver is within tolerance and another to check the sensitivity at mid frequency. Passband testing may be separated into Low Group Channels (e.g., 697, 770, 852, and 941 Hz) and High Group Channels (e.g., 1209, 1336, 1477, and 1633 Hz). Tests are then conducted at the band edges (minimum and maximum) to determine if the receiver is within tolerance at all frequencies. All passband testing is usually done at the same power level (e.g., −5 dBm).

4.10 The sensitivity test may be done at mid-frequency (such as 941 Hz) with variation of input power level until the Receiver does not respond.

4.11 **OPERATOR MAINTENANCE**

4.12 If the Precision Oscillator's OVERLOAD lamp lights during TOUCH-TONE® testing, it indicates that a short circuit or low impedance path exists in the receiver under test. If it is a momentary condition, the OVERLOAD lamp extinguishes when the low impedance is removed. The Precision Oscillator cannot be damaged by sustained overloads. However, if one occurs, the cause of the overload should be corrected before continuing with testing.

4.13 The +5 Vdc power supply in the Precision Oscillator is protected by a crowbar circuit which shuts off the supply if excessive current is drawn. The ±15 Vdc supplies, as well as the entire Precision Oscillator, are protected by a 1 ampere fuse in series with the input ac power source voltage. The fuse is located on the rear panel. If the POWER lamp goes out, check and replace the fuse if found to be defective. A momentary overload may be corrected by this means. However, if the problem re-occurs, the cause of the failure must be corrected. Refer to Section 6, Maintenance, for troubleshooting aids.

SECTION 5

THEORY OF OPERATION

5.1 DIGITAL FREQUENCY SYNTHESIS

5.2 The Precision Oscillator uses digital frequency synthesis techniques to generate sinewaves in the frequency range of 100.0 Hz to 9,999.9 Hz in steps of 0.1 Hz. The digital synthesizer is operated from a master 10.48576 mHz oscillator, and has a frequency select input in BCD notation.

5.3 Using these two parameters, the synthesizer calculates digital amplitude values of the sinewave continuously and directly. The digital values are converted to voltage levels by a digital-to-analog (DAC) converter which results in a staircase-type approximation of a sinewave at the selected frequency.

5.4 An example of frequency synthesis by digital means is shown in Figure 5—1. This technique uses a read-only-memory (ROM) which contains the trigonometric values for the sine function in sequential locations.

NOTE

The example shown in Figure 5—1 assumes that only 128 amplitude values are stored for the entire 360° sinewave, whereas the actual ROM used in the Precision Oscillator contains 2048 discrete amplitude values for the sine of 0° to 90° (8,192 values for one complete cycle of 360°).

5.5 Since the sinewave is symmetrical at 0° and 180° and 90° and 270°, only the 0° to 90° values for quadrant I are stored. Through appropriate logic circuits, the polarity of the amplitude values is changed for each of the remaining three quadrants of the sinewave (II, III, and IV).

5.6 The examples in Figure 5—1 show that for a 100 Hz output, all 128 amplitude points are used. For twice that frequency, only half the points are used; however, the maximum and minimum values are always used (0, 32, 64, 96, and 128 in the example). At 200 Hz every other amplitude point is used. At 400 Hz every fourth point is used, and so forth.

5.7 The resulting waveforms at the output of the DAC form a staircase approximation of the selected sinewave. The waveforms of Figure 5—1 show that fewer amplitude points are used at higher frequencies.

5.8 The staircase output is applied to a low pass filter which eliminates the upper harmonic frequencies and produces an essentially pure sinewave output.

5.9 Frequency control is accomplished by selecting the corresponding phase angle (or phase increment) of the 360° sinewave that is to be read from the ROM. For a frequency of 12.8 Hz, 2048 phase angles are read out for each 90° quadrant (total of 8,192 discrete amplitude points). Phase increments (amplitude points) for representative frequencies are shown below.

5.10 The ROM contents are read out by a fixed frequency master oscillator. The change in ROM address depends on the phase increment selected. Thus, at higher frequencies, more locations are skipped since the phase increment is larger; and at lower frequencies fewer locations are skipped because the phase increment is smaller.

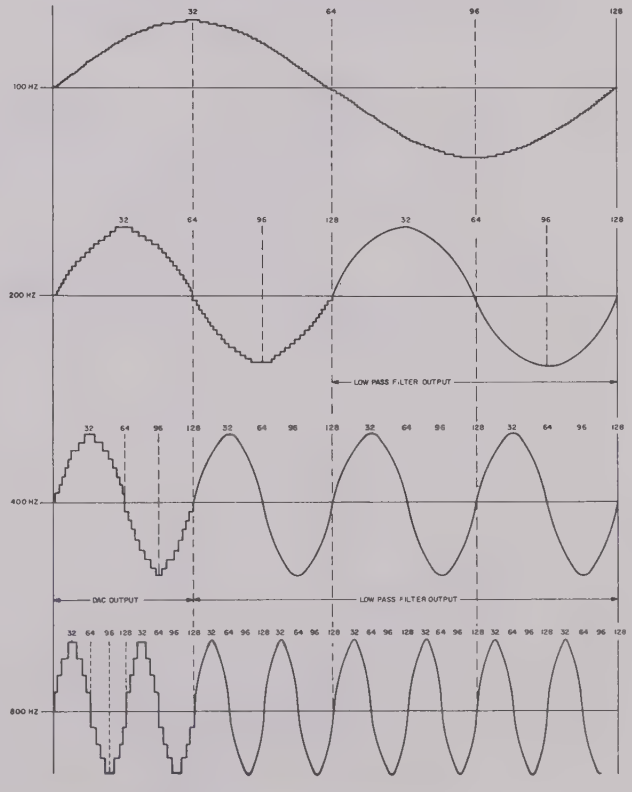

Figure 5—1. Digital Frequency Synthesis Waveform

5.11 BLOCK DIAGRAM DESCRIPTION (SEE FIGURE 5—2)

5.12 The five frequency select switches on the Precision Oscillator front panel provide BCD inputs of the phase increment corresponding to the desired frequency. Since each switch selects a decimal digit from 0-9, a 4-bit BCD code is used for each digit.

5.13 The 20 BCD inputs (five, 4-bit digit switch codes) are converted to binary in a serial fashion. Ten successive samples of the input BCD codes are made at a 1.48576 mHz rate, and each partial conversion is presented to the A WORD input of a 20-bit adder. The adder is referred to as the Phase Accumulator.

5.14 After 10 clock pulses, the BCD inputs are completely converted to binary. At that time the ROM output is latched by a 0.148576 mHz clock.

NOTE

During each of the 10 partial BCD-to-binary conversions, the input address lines to the ROM change, and the ROM output data lines change accordingly. However, the DAC input is not latched until the conversion is completed.

5.15 At this time a binary amplitude value stored in the ROM is converted to a dc voltage between −5 volts and +5 volts. The specific voltage amplitude depends upon the particular address of the ROM's sinewave look-up table which has been selected.

5.16 Ten clock pulses later, the BCD inputs are again completely converted to binary and the same binary number is present at the A WORD input to the adder. Thus, for example, if the Adder SUM output is initially 0 and the phase increment is 1000 decimal (corresponding to a frequency of 100.0), the first 10 clock pulses to the Adder results in decimal 1000 on the B WORD and SUM lines. After the second group of 10 clocks, 1000 is still on the A WORD input; however, 2000 is on the B WORD and SUM lines. Thus, the Adder operates as an incremental counter, counting from 1000 to 2000 to 3000 etc. Obviously the count increment changes as a function to the selected frequency.

5.17 The counter overflows at a count of 1,049,000 decimal which occurs at the end of one cycle of the output sinewave (actual count is 1,048,576). The Adder (Phase Accumulator) continues to increment the count independent of overflow.

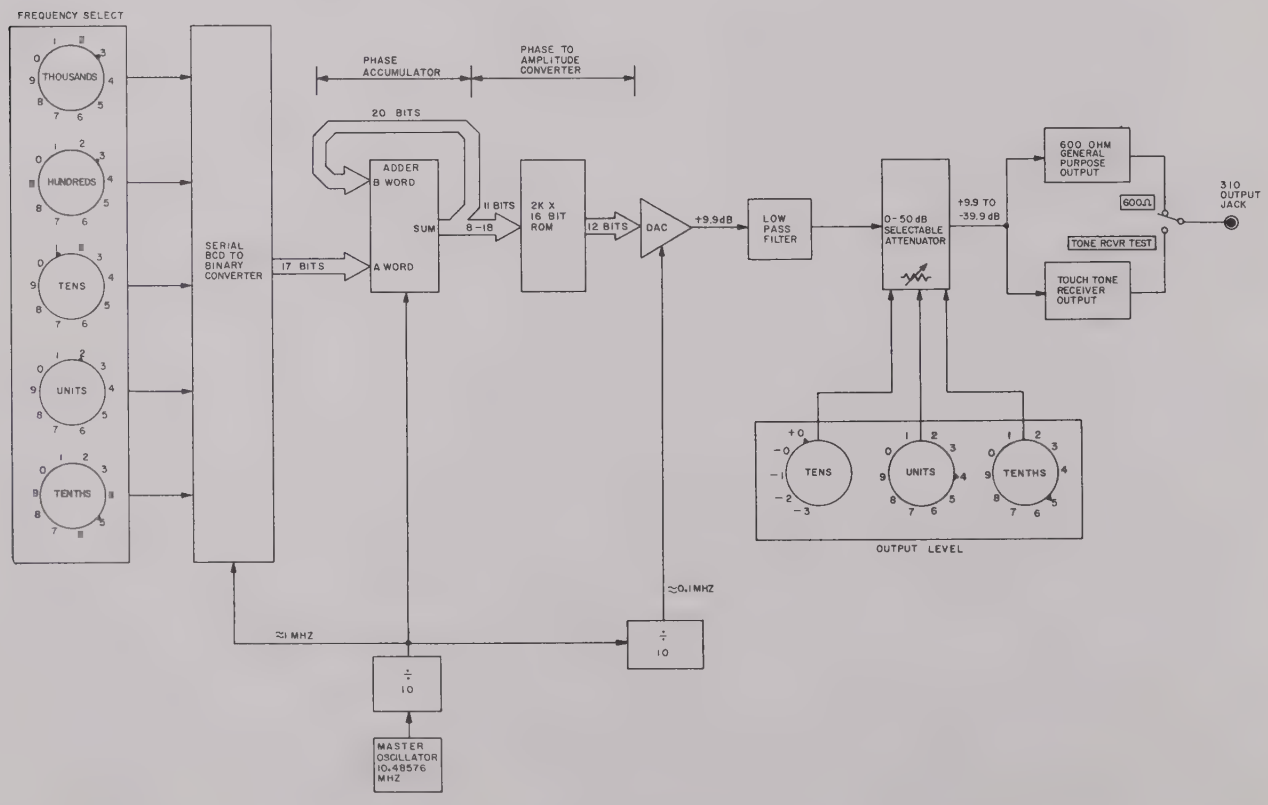

Figure 5—2. Block Diagram

5.18 As the Phase Accumulator adds phase increments, bits 8 through 18 provide address information to the ROM. These 11 bits allow the ROM to be addressed in increments from 0 to 2047, selected by the frequency switches. Bits 8—18 from the Phase Accumulator are ROM address bits 1—11. These bits count from 0 to 2047 and back to 0 four times as the 20-bit Phase Accumulator counts to an overflow condition.

5.19 The incremental count from 0 to 2047 is done in steps corresponding to the phase angle of the selected frequency (see Table 5—1). Each of the four cycles through the ROM correspond to one of the four quadrants of the output sinewave (I—IV). The digital amplitude values stored in the ROM are converted to dc voltages between +5V and —5V by the DAC. Logic circuits (not shown on Figure 5—2) cause the ROM output values (DAC input) to follow the pattern shown in Table 5—2.

5.20 The staircase output of the DAC at 9.9 dB is applied to a lowpass filter to remove the high frequency harmonics and send an essentially pure sinewave to the 0—50 dB Selectable Attenuator. The attenuator has a resistor network which is controlled by the three OUTPUT LEVEL switches on the front panel to select any level between +9.9 and —39.9 dBm in 0.1 dB steps.

5.21 The selected level is applied to a 600 ohm general-purpose output impedance network and a TOUCH-TONE® output impedance network. The desired output (general-purpose or TOUCH-TONE®) is selected by a front panel switch and applied to the front panel 310 jack.

5.22 **FUNCTIONAL SCHEMATIC DESCRIPTION (See Figure 7—1)**

5.23 FREQUENCY SELECTION

5.24 Input frequency selection has an absolute range of approximately 100,000 which corresponds to frequencies from 100.0 to 9,999.9 Hz. This range is in increments of 1 which corresponds to 0.1 Hz. To count 100,000 steps (actually 98,999) requires 17 binary bits (2^{16} = 65,536 and 2^{17} = 131,072). Thus, at a frequency of 100.0 Hz, the phase increment used is 1000; 1,000.0 Hz is 10,000; and so forth.

Table 5—1. Frequency vs Phase Increments

FREQUENCY (HZ)	PHASE INCREMENTS/ CYCLE	DEGREES/ INCREMENT
12.8	8,192	0.044
102.4	2,040	0.176
3,276.8	28	12.8
9,930.4	12	30.0

NOTE

Useable frequency range is from 100.0 to 9,999.9 Hz although selector switches range from 000.0 to 9,999.9 Hz.

Table 5—2. ROM Input/Output Switching

QUADRANT	ROM ADDRESS	AMPLITUDE OUTPUTS
I	Increment (0—2047)	Normal (0V to +5V)
II	Decrement (2047—0)	Normal (+5V to 0V)
III	Increment (0—2047)	Inverted (0V to —5V)
IV	Decrement (2047—0)	Inverted (—5V to 0V)

5.25 Although frequencies below 100.0 Hz may be selected from the front panel, the minimum useable frequency is 100.0 Hz (1000_{10}) and the minimum frequency increment is 0.1 Hz (1_{10}).

5.26 The twenty BCD inputs from the frequency switches are converted to seventeen binary signals (using chips U23-U33) according to the Boolean Equations shown in Table 5—3.

5.27 SERIAL CODE CONVERSION

5.28 Timing is derived from 10.48576 mHz crystal-controlled oscillator U42 and two decade counters, U40 and U41. As shown in Figure 5—3, the U42 output is divided-by-ten using Decade Counter U41. The Q_C output of U41 changes at a 1.048576 mHz rate and is used to clock latches U13 through U16 at the output of the Phase Accumulator Adder. The Q_D output of U41 is the clock input to the second Decade Counter U40. The Q_A through Q_D binary outputs of U40 are applied to 1 of 10 Decoder U39 which sequentially enables various combinations of the BCD-to-Binary Conversion Gates U23 through U38.

5.29 The Q_D output occurs at 0.1048576 mHz and is used to clock latches U3 and U4 at the input to the DAC. Thus, three basic frequencies are used as follows:

a. 10.48576 mHz — Master Clock

b. 1.48576 mHz — Clocks BCD-to-Binary Converter and Adder

c. 0.148576 mHz — Clocks latch input to DAC after each conversion

5.30 The 1 of 10 Decoder output changes at 1.48576 mHz with each Q_D input pulse to Decade Counter U40. The 10 Decoder output lines are enabled one at a time in sequence 0, 1, 2, 3, etc. Each line enables a partial code conversion to be performed.

5.31 The results from each conversion appear at the inputs to 4-bit Adders U17 through U21 on the A WORD input. This input is added to the previous sum which is present on the B WORD input and the new sum is clocked into Latches U13—U16.

5.32 After 10 successive conversions, the BCD-coded number is completely converted to its 17-bit binary equivalent. At that time the latches contain the current, accumulated phase increment which provides address bits 8 through 18 to the ROM. The 11-bit digital amplitude value at the stored location is latched into U3 and U4 by the 0.1048576 mHz clock from U40. Thus, each serial conversion occurs at a 1.048576 mHz rate and a complete digit is converted at a 0.1048576 mHz rate (10 serial conversions).

Table 5—3. BCD To Binary Conversion

BIT	BOOLEAN EQUATION
1	$BIN_1 = BCD_1$
2	$BIN_2 = BCD_2 + BCD_{10}$
3	$BIN_4 = BCD_4 + BCD_{20} + BCD_{100}$
4	$BIN_8 = BCD_8 + BCD_{10} + BCD_{40} + BCD_{200} + BCD_{1000}$
5	$BIN_{16} = BCD_{20} + BCD_{80} + BCD_{400} + BCD_{2000} + BCD_{10000}$
6	$BIN_{32} = BCD_{40} + BCD_{100} + BCD_{800} + BCD_{1000} + BCD_{4000} + BCD_{20000}$
7	$BIN_{64} = BCD_{80} + BCD_{100} + BCD_{200} + BCD_{1000} + BCD_{2000} + BCD_{8000} + BCD_{40000}$
8	$BIN_{128} = BCD_{200} + BCD_{400} + BCD_{1000} + BCD_{2000} + BCD_{4000} + BCD_{80000}$
9	$BIN_{256} = BCD_{400} + BCD_{800} + BCD_{1000} + BCD_{2000} + BCD_{4000} + BCD_{8000} + BCD_{10000}$
10	$BIN_{512} = BCD_{800} + BCD_{1000} + BCD_{2000} + BCD_{4000}\ BCD_{8000} + BCD_{10000} + BCD_{20000}$
11	$BIN_{1024} = BCD_{2000} + BCD_{4000} + BCD_{8000} + BCD_{10000} + BCD_{20000} + BCDD_{40000}$
12	$BIN_{2048} = BCD_{4000} + BCD_{8000} + BCD_{20000} + BCD_{40000} + BCD_{80000}$
13	$BIN_{4096} = BCD_{8000} + BCD_{40000} + BCD_{80000}$
14	$BIN_{8192} = BCD_{10000} + BCD_{80000}$
15	$BIN_{16384} = BCD_{20000}$
16	$BIN_{32768} = BCD_{40000}$
17	$BIN_{65536} = BCD_{80000}$

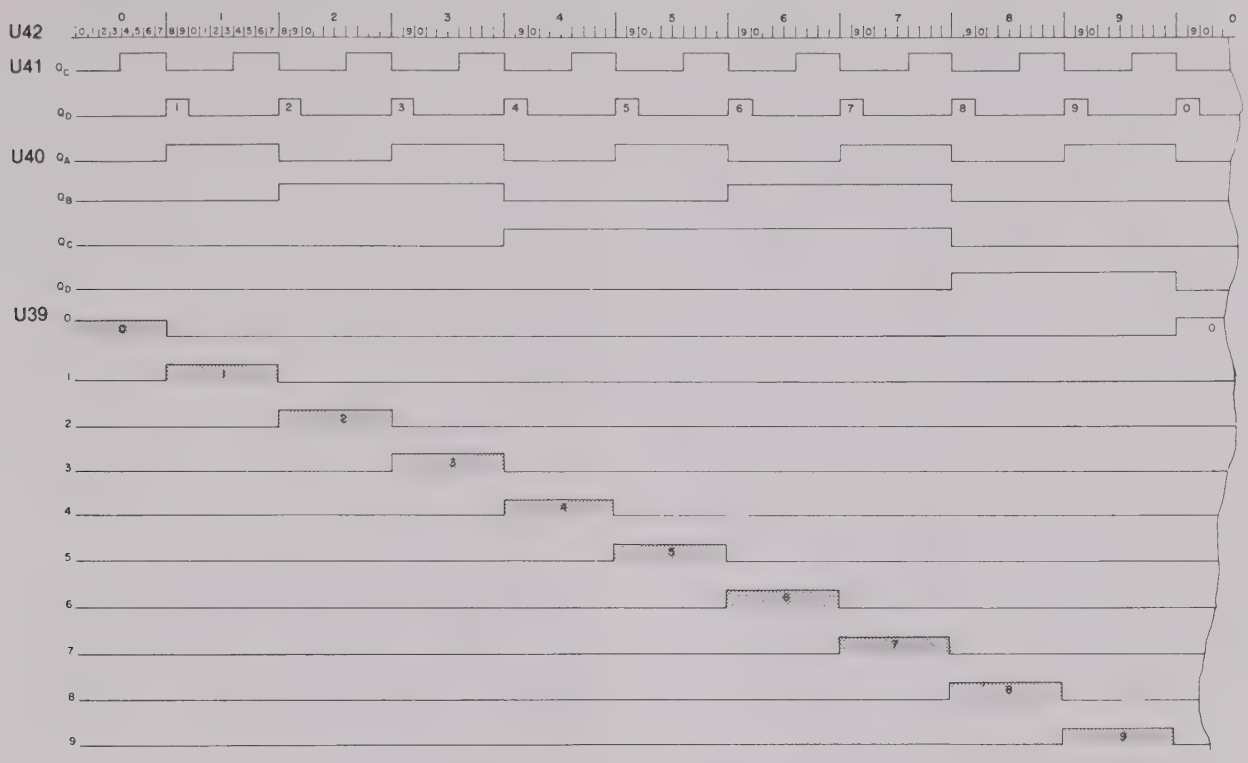

Figure 5—3. Timing Diagram

5.33 During the 10 partial conversions, the DAC input does not change although the ROM addresses and output bits change. The 12-bit latch U3 and U4 retains the previous ROM output until the next valid phase increment is present on the ROM's input address lines. At that time the latch is clocked and the previous digital value is replaced with the current value.

5.34 PHASE ACCUMULATOR OPERATION

5.35 The five, 4-bit Adders, U17-U21, and the 20-bit latches, U13,-U16, comprise the Phase Accumulator. Feedback from the SUM output through the latches and back to the B WORD inputs of the Adder make the Phase Accumulator an incremental counter.

5.36 The A WORD input is the phase increment corresponding to the selected frequency. This binary number may be anywhere from 1000_{10} to $99{,}999_{10}$ for output frequencies of 100.0 Hz to 9,999.9 Hz. Thus, the input may range from 1000, 1001, 1002. . .up to 99,999. The accumulator continues to add the selected phase increment to the previous sum until overflow occurs at a count of 1,048,576 (2^{20}). The **rate** of overflow equals the **output frequency** selected by the front panel switches. Accumulation then begins again for the next cycle of the sinewave.

5.37 The time it takes the accumulator to overflow depends on the phase increment value which, in turn, is a function of the selected output frequency. For example, at the lowest useable output frequency of 100.0 Hz, the phase increment is 1000 and the accumulator counts 1000, 2000, 3000. . .1,049,000 to overflow. This requires 1,049 clock pulses. The accumulator is clocked at 1.048576 mHz; however, its output is used only every 10 clock pulses because of the serial conversion applied to the BCD-codes from the frequency selection switches. Thus, the effective clock frequency is 0.1048576 mHz. The time required to overflow is:

$$\text{Time} = \frac{1049 \text{ cycles}}{0.1049 \times 10^6 \text{ cycles/sec}}$$

$$\text{Time} = 10 \text{ msec}$$

This is the period of a 100.0 Hz sinewave.

5.38 ROM ADDRESSING

5.39 Bits 8 through 18 from the Phase Accumulator provide address information to the ROM. Table 5—4 summarizes the addressing scheme.

Table 5—4. ROM Addressing

ACCUMULATOR OUTPUT

Bit No.	18	17	16	15	14	13	12	11	10	9	8
Binary	2^{17}	2^{16}	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	2^{7}
Decimal	131,072	65,536	32,768	16,384	8,192	4,096	2,048	1,024	512	256	128

ROM INPUT

Bit No.	11	10	9	8	7	6	5	4	3	2	1
Binary	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}
Decimal	1024	512	256	128	64	32	16	8	4	2	1

5.40 For an input frequency of 12.8 Hz, the phase increment is 128_{10}. As the Phase Accumulator counts in increments of 128, bits 8 through 18 step in binary fashion and the resulting address inputs to the ROM cycle from 0 to 2047, using all decimal amplitude values from the ROM.

NOTE

The example frequency of 12.8 Hz is selectable from the front panel; however, it is not within the normal operating range.

5.41 The closest binary multiple frequency to the 100.0 Hz minimum, is 102.4 Hz. At this frequency the phase increment is 1024 and 2040 addresses (2048-8) are used for each quadrant. At a frequency of 3,276.8 Hz the phase increment is 32,768 (2^{15}) and the ROM is addressed in multiples of 256 (i.e., 0, 256, 512, 1024, 1280, 1536 and 1792). Thus, 7 points per quadrant or 28 per cycle are used.

5.42 Near the upper frequency limit, 9,830.4 Hz may be used as a convenient example. Its phase increment is 98,304 which uses bits 16 and 17 (32,768 plus 65,536). These bits correspond to ROM address bits for 256 and 512. As the Phase Accumulator counts, bits 16, 17, and 18 (9, 10, and 11 inputs to ROM) cycle as follows:

1024	512	256	COUNT
0	0	0	0
0	1	1	768
1	1	0	1536
0	0	0	2048/0

5.43 Thus, near the upper limit, three amplitude points per quadrant are used (12 per cycle).

5.44 DIGITAL AMPLITUDE CONTROL BY QUADRANT

5.45 The ROM stores digital amplitude values for quadrant I only. As shown previously in Table 5—2, these same values are used for quadrants 2, 3, and 4 by: (a) causing the address bits to decrement during quadrants II and IV, and by (b) inverting the amplitude points during quadrants III and IV.

5.46 This is accomplished by sensing bits 19 and 20 from the Phase Accumulator and using exclusive - OR gates (XOR) U10-U12 for address inversion (decrementing) and XOR's U5-U7 for amplitude inversion. Bits 19 and 20 cycle as shown below for each quadrant as the Phase Accumulator counts to overflow:

QUADRANT	BIT 20	BIT 19
I	0	0
II	0	1
III	1	0
IV	1	1

Bit 20 is used to invert the ROM output to form the negative half of the sinewave and bit 19 is used to invert the ROM address input to cause decrementing during quadrants II and IV.

5.47 Any two input XOR gate may be used as a selective inverting gate as shown below:

Truth Table With Alternating Inputs

A	B	C
0	0	0
1	0	1
0	1	1
1	1	0

Truth Table With Input A Always High (Inverting)

A	B	C
1	0	1
1	1	0

Truth Table With Input A Always Low (Non-Inverting)

A	B	C
0	0	0
0	1	1

5.48 Thus, as shown above, anytime input A is held low, an XOR is simply a non-inverting "single input" OR gate, whereas if input A is held high (selective input) the XOR becomes a controlled inverter.

5.49 When Bit 19 from the Accumulator is low during quadrant I and III, XOR gates U10, U11, and U12 function as "single input" OR gates and the ROM addresses increments normally. During quadrants II and IV, Bit 19 is high and the XOR's invert the address bits (1's complement), causing the ROM output to decrement. This provides the decreasing amplitude points required for quadrants II and IV.

5.50 Similarly, bit 20 is low during quadrants I and II and XOR's U5, U6, and U7 have no effect on the ROM output. During quadrants III and IV, when Bit 20 is high, the XOR's invert to provide the values for the negative half cycle of the sinewave.

5.51 The complement of Bit 20 ($\overline{BIT20}$) is applied to 12-bit latch U3 and U4 as the sign bit input to current output DAC U2. During quadrants I and II, the Sign Bit is high and the DAC output current ranges from 0 to 1 to 0 mA. Current-to-voltage converter U1 changes the 0 to 1 to 0 mA range into a 0 to +5 to 0 voltage range.

5.52 When $\overline{BIT\ 20}$ goes low during quadrants III and IV it causes the 1 mA DAC current output to reverse direction. U1 converts this to a range of 0 to −5 to 0 volts. The sinewave output from U1 at 10 V p/p (+5 V and −5 V) is applied to a lowpass filter on the Analog Board.

5.53 LOWPASS FILTER (SEE FIGURE 5−4)

5.54 This network consists of L1,L2,C1,C2, and C3. As shown in Figure 5−4, it is a passive, lowpass filter with a 3 dB point at 20 kHz and has 30 dB per octave roll-off. It passes all frequencies below 12 kHz without attenuation.

5.55 Impedance matching is provided by R1,R2,R70 and R71.

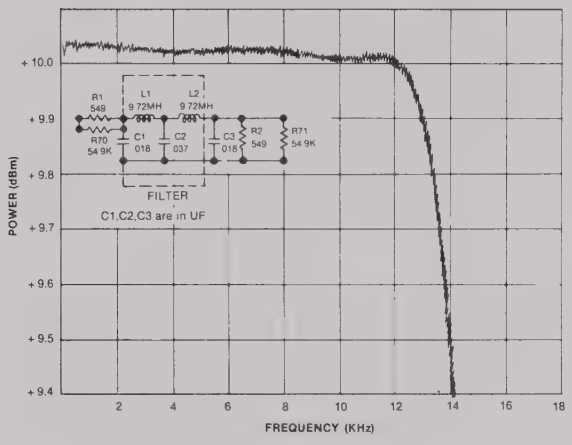

Figure 5−4. Lowpass Filter

5.56 NEGATIVE − GAIN AMPLIFIERS (ATTENUATORS)

5.57 Output signal attenuation is provided with three stages of negative-gain amplifiers. The first stage attenuates in steps of 0.1 dB (U1-B, S10 and S8; R5 through R23). The next stage is in steps of 1.0 dB (U2-A, S9 and S8, R25 through R43), and the last stage is in ten dB steps of −10, −20, and −30 dB (U2-B, S8, R45 through R51).

5.58 The attenuation is selected from the three front panel switches in .1 dB steps from +9.9 dB to −39.9 dB. This negative-gain technique reduces output noise to a minimum since the initial input signal is relatively large and is then attenuated. The large input signal is provided by Operational Amplifier U1 on the Digital Board which converts the ±1 mA current output of DAC U2 to a 10 V p/p voltage output (±5 V).

5.59 Figure 5–5 is a simplified diagram of the attenuator switching scheme. The leftmost switch on the front panel selects the attenuation of the last stage as shown. For +dB outputs, the last stage contributes zero attenuation while the two preceding stages add up to 9.9 dB. For –dB levels, the last stage adds attenuation as follows:

POSITION	ATTENUATION (dB)
–0	9.9
–10	19.9
–20	29.9
–30	39.9

The preceding stages add from 0 to 9.9 dB to the last stage attenuation to determine the selected output.

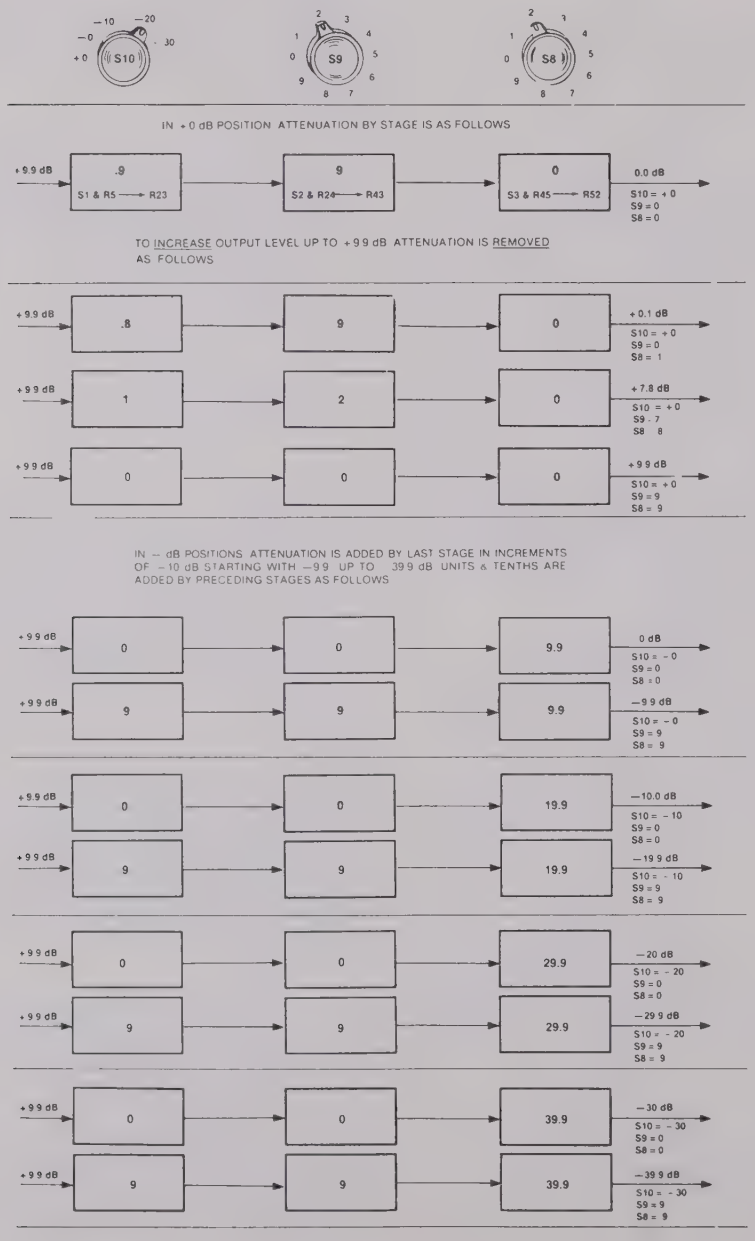

Figure 5–5. Attenuator Switching

5.60 In summary, +9.9 dB is always present at the input to the first attenuation network. For + dB output levels, attenuation is removed by S10 and S9 to increase the output above 0 dB while for −dB output levels, attenuation is always added by S10 and S9 to the attenuation selected by S8. The attenuated signal is applied to both the Tone Receiver Output and the General Purpose Output amplifier circuits.

5.61 TONE RECEIVER TEST OUTPUT

5.62 The output of the attenuation network is applied to Operational Amplifier U4 in the Tone Receiver Output network. Amplifier U4 is a voltage follower capable of +9.9 dB to −39.9 dB into a 900 ohm to 40 K ohm load over the full range of 100 Hz to 10 kHz.

5.63 Diodes CR2,CR3,CR8, and CR9 provide protection against high voltage transients. The output is applied to switch S2 and ac coupled through capacitor C8 providing dc blocking up to 150 Vdc. The output signal appears between the TIP (signal) and RING (ground) of the 310 jack. The sleeve connection is not used.

5.64 The TONE RCVR output is monitored by overload detector circuit U3A and U3B. This circuit illuminates the OVERLOAD lamp if the output load pulls the output out of calibration over the range of 650 Hz to 1700 Hz.

5.65 Overload circuit amplifier U3A senses the current supplied to U4 through R53. During normal operation, the ac ripple component of the current is toc small to be sensed. If an overload occurs, the excessive ac ripple increases above the threshold of amplifier U3A. This is determined by OFFSET ADJ R77. The amplifier gain is held relatively constant over the range of output levels by switching in resistor R76,R79,R80,R81, or R82.

5.66 The amplified ac output is rectified by CR1, C5 and R74. When the dc level on C5 exceeds the bias on comparator U3B (approximately 1 volt), the output switches positive. This turns on switch Q1 which lights OVERLOAD lamp DS2.

5.67 GENERAL PURPOSE OUTPUT

5.68 This circuit provides a 600 ohm balanced output impedance. Its' output is transformer-coupled for general purpose testing of any devices that have a 600 ohm input impedance within the frequency and power ranges of the Precision Oscillator.

5.69 Resistor R65 adjusts the output impedance to 600 ohms and is normally calibrated at 1 kHz. The LEVEL ADJ, R62, calibrates the 600 ohms output level. Diodes CR4 and CR5 suppressors E1 and E2 provide high voltage protection.

5.70 Thermistor RT-1 provides output impedance compensation for changes in ambient temperatures over a range of 0° to 50°C. Capacitors C6 and C7, in parallel with the secondary of T1, compensate for phase shift at 10 kHz.

5.71 DC POWER SUPPLIES

5.72 Three dc power supplies, housed in an open frame, provide ±15 Vdc and +5 Vdc operating voltages for the Precision Oscillator. All voltages are adjustable. The +5 volt supply incorporates a crowbar circuit with an adjustable threshold for over-voltage protection. It is normally factory set to operate at +6.5 Vdc. Current limiting is also provided with the +5 volt supply and may be adjusted from near zerc to slightly greater than 100% of the rated load.

5.73 The supplies use an input step-down, tapped secondary power transformer plus rectifiers and filters. Series regulation is provided with IC sensing amplifiers. Refer to Section 7 for the schematic diagram of the power supply. Basic specifications are listed below

INPUT POWER:	105 to 125 Vac, 57 to 63 Hz
OUTPUTS:	+5 Vdc, ±5% @ 1.0 A; ±15 Vdc, ±2% @ 0.5 A
LINE REGULATION:	0.10% for change from minimum to maximum output
LOAD REGULATION:	0.10% for change from minimum to maximum output
RIPPLE & NOISE:	5 mV P/P
TEMPERATURE COEFFICIENT:	0.03%/°C

SECTION 6

MAINTENANCE

6.1 This section provides instructions for maintaining the Precision Oscillator at its optimum performance level. Conventional troubleshooting charts are included to aid in diagnosing a malfunction to a replaceable assembly or, in some cases, to a replaceable part. In addition, calibration procedures are provided to ensure that the Precision Oscillator is within its operating tolerances. Adjustments and troubleshooting hints are provided separately for the dc power supply.

6.2 TROUBLESHOOTING

6.3 For overall trouble identification, refer to Table 6—1.

6.4 DC POWER SUPPLY TROUBLESHOOTING

6.5 Since most malfunctions are a result of semiconductor failure it is simplest to handle field problems by parts replacement. Ohmmeter checks are adequate for determining the integrity of series regulator transistors, driver transistors, and rectifier diodes. The power regulator transistors and the integrated circuit regulators are socket mounted and easily replaceable. In each case, simply replace the defective component with an equivalent component. Ratings can be determined by color codes on the components or by direct markings, depending upon the type of component.

6.6 DC POWER SUPPLY ADJUSTMENTS

6.7 The location of output voltage controls R112 for the +5 volts and R212 for the ±15 volts are identified on the P.C. board as VADJ. The +5 volt current cutback limit adjustment R105 is also identified on the board. It is factory set, but can be adjusted from near 0 to slightly over 100% of rated load. If re-adjusted, use care to insure that maximum current ratings are not exceeded.

CAUTION

Improper adjustment of the current or voltage controls can cause damage and/or failure to the supply.

6.8 Diode CR105 crowbars the +5-volt output. The crowbar turn-on level is adjustable with OVP control R115. and is normally set to 6.5 volts. The crowbar may be reset after triggering by removing and re-applying input power.

Table 6—1. Troubleshooting Guide

SYMPTOM	POSSIBLE CAUSE AND LOCATION
1. POWER lamp does not light when power switch is on.	a. Fuse at rear panel defective. b. POWER switch S1 defective. Measure 115 Vac across input and output terminals of switch S1. If not present at output, replace switch. c. If AC is present at output of switch S1, replace lamp DS1. If problem is still present and fuse continues to blow, primary of transformer T1 in power supply may be shorted or power supply may be otherwise defective. Refer to pargraph 6.4.
2. OVERLOAD lamp DS2 remains on constantly with no load connected.	Current Sensor and Lamp Driver U3 or switch Q1 on Analog Board defective. Check Q1 and LED.
3. a. Output power level does not correspond to front panel switch settings.	a. DAC U2 or voltage converter U1 defective. On Digital Board, check for ±5 Vdc at U1-6 (J1-Y).

Table 6—1. (Cont'd)

SYMPTOM	POSSIBLE CAUSE AND LOCATION
b. Output level error at +0 dBm position only.	b. Attention network resistors R51 and R69 on Analog Board defective, replace.
c. —0 dBm position only.	c. Replace R49 and R50
d. —10 dBm position only.	d. Replace R48
e. —20 dBm position only.	e. Replace R46 and R47
f. —30 dBm position only.	f. Replace R45
g. Output level error on units switch positions as shown in adjacent column.	**+ dBm / RESISTOR(S) / —dBm** 0 / R25 and R26 / 9 1 / R27 and R28 / 8 2 / R29 and R30 / 7 3 / R31 and R32 / 6 4 / R33 and R34 / 5 5 / R35 and R36 / 4 6 / R37 and R38 / 3 7 / R39 and R40 / 2 8 / R41 and R42 / 1 9 / R43 / 0
h. Output level error on tenths switch positions as shown in adjacent column.	**+ dBm / RESISTOR(S) / — dBm** .0 / R5 and R6 / .9 .1 / R7 and R8 / .8 .2 / R9 and R10 / .7 .3 / R11 and R12 / .6 .4 / R13 and R14 / .5 .5 / R15 and R16 / .4 .6 / R17 and R18 / .3 .7 / R19 and R20 / .2 .8 / R21 and R22 / .1 .9 / R23 / .0
4. a. Output frequency does not correspond to front panel switch settings	a. Failure of components on Digital Board. Analyze and correct problem per following.
b. Incorrect output between frequencies listed in adjacent column.	**FREQ (Hz) / FREQUENCY INCREMENT (Hz) / CHIPS** 0—1.5 / 0.1 / U21 and U16 1.6—12.7 / 1.6 / U20 and U15 12.8—204.7 / 12.8 / U19 and U15 204.8—3,276.7 / 204.8 / U18 and U14 3,276.8—9,999.0 / 3,276.8 / U17 and U13

Table 6—1. (Cont'd)

SYMPTOM	POSSIBLE CAUSE AND LOCATION
c. Incorrect output in switch positions shown in adjacent column.	**SWITCH** **CHIPS** Tenths U21 Units U21,U20 Tens U21, U20, U19 Hundreds U21, U20, U19,U18 Thousands U20, U19, U18, U17
5. Abnormal output waveforms	a. Defective Lowpass Filter. Troubleshoot/replace L1, L2, and C1, C2 on Analog Board. b. Defective voltage converter U1 or DAC U2 on Digital Board. Select 12.8 Hz on front panel and observe symmetrical, stepped-sinewave approximation at 10 V p/p between J1-Y and 21. Replace U1 or U2 as necessary. c. ROM output latches defective or not being clocked. On Digital Board, check for 0.148576 MHz pulses at J1-B. If present, replace chips U3 and U4. If not present, check crystal oscillator U42 and decade counter U41 and U40 for proper operation at J1-20, J1-2 and J1-B, respectively. Replace U40,U41, or U42 as required. d. Defective ROM('s), Check that input address bits A0 through A10 cycle in binary order when 12.8 Hz is selected. If they do not, replace U10, U11 or U12 as required. If they cycle correctly, replace U8 and U9 on Digital Board or replace board.

6.9 CALIBRATION

6.10 Calibration consists of checking that the output frequency and power levels agree with the front panel control settings. Long term stability of the Precision Oscillator as specified in Section 2 (Performance Specifications), is such that calibration is recommended on an annual basis. The five tests and adjustments required are summarized below. Detailed procedures and test set-ups are provided in the following paragraphs.

NOTE

These tests are inter-dependent and should be performed in the order listed below.

1. Tone receiver test output of 9,999.9 Hz is selected and master oscillator frequency is adjusted as required to obtain 9,999.9 Hz.

2. General purpose output impedance is adjusted by measuring the return loss at 1000 Hz and at 10,000 Hz. Impedance is adjusted until equal return loss ±1 dB is obtained at both frequencies.

3. Tone receiver output of oscillator is checked at 1000 Hz for 0 dBm into 900 ohms (±1%). Lowpass filter output is adjusted as necessary to obtain .77459 volts (±.1%).

4. General purpose output is checked at 1000 Hz for 0 dBm into 600 ohms (±1%). Output level adjusted as necessary to obtain .77459 volts (±.1%).

5. Overload circuit is checked at 1000 Hz and +9.9 dBm into a 700 ohm load. OFFSET ADJ. adjusted as necessary to cause lamp to light with 700 ohm load and to go out with increased load (less than 900 ohms).

6.11 TEST EQUIPMENT REQUIRED

6.12 Test equipment necessary to perform the calibration procedures is listed in Table 6—2.

CAUTION

Test cords must be cleaned thoroughly prior to use to minimize contact resistance.

Table 6—2. Test Equipment Required

ITEM	MODEL	NOTES
Test Cord	Western Electric 2W6A	Cord has one 310 plug and two 59 cord tips.
Tansmission Test Set	Northeast Electronics TTS 44	
Volt-ohmmeter	HP 427A	Battery operated
Frequency Counter	HP 5328A	
Differential Voltmeter	Fluke 931B	
Decade Resistance Box	Clarostat, Model 260	
Impedance Bridge	Precision 600 ohm bridge attenuator with SPST switch	(See Figure 6—2)
Jumper Wire		For grounding R65 on Analog Board during Impedance calibration
Precision Load	600 ohms, ±0.1%, ¼ watt	Simulate load
Precision Load	900 ohm, ±0.1%, ¼ watt	Simulate load
Insulated Alignment Tool		Adjust master oscillator.

6.13 OUTPUT FREQUENCY CALIBRATION

1. Remove oscillator top cover.

2. Connect test set-up according to Figure 6—1. Equivalent test equipment may be used.

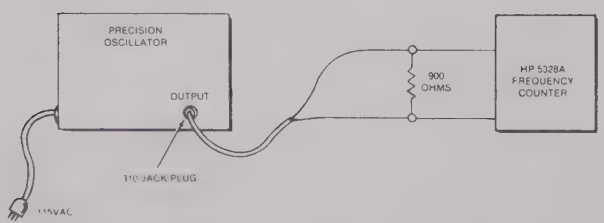

Figure 6—1. Frequency Calibration Test Set-Up

3. Energize Precision Oscillator and test equipment. Allow 15-minute warm-up for test equipment.

4. Place 600 Ω /TONE RCVR TEST switch to TONE RCVR TEST position.

5. Preset output level switches to a convenient level adequate to drive the test equipment.

6. Preset FREQUENCY switches to 9,999.9 Hz.

7. If necessary, adjust FREQ control on Digital Board to obtain 9,999.9 Hz on frequency counter.

8. Replace top cover.

9. Turn off oscillator and test equipment.

6.14 GENERAL PURPOSE OUTPUT IMPEDANCE CALIBRATION

1. Remove bottom cover.

2. On the Analog Board, connect a jumper wire between pin 6 of chip U5 and circuit ground (Refer to Figure 7—9).

3. Place 600Ω/TONE RCVR TEST switch to 600Ω position.

CAUTION

Do not connect oscillator power cord during this test.

4. Connect test set-up as shown in Figure 6—2. Do not connect Precision Oscillator until step 8.

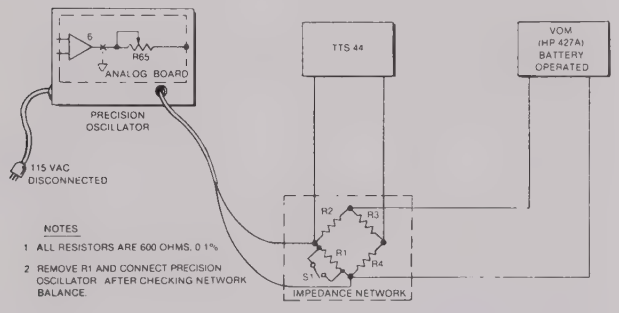

Figure 6—2. General Purpose Output Impedance Test Set-Up

5. Turn-on test equipment.

6. With switch S1 closed, set TTS 44 to 1000 Hz for 0 dBm as indicated on VOM.

7. Open S1. The indication on the VOM should be —50 dBm or greater.

NOTE

With switch S1 closed, a short circuit is simulated. This establishes the reference level for return loss measurements. The difference between the short circuit reference and the indication with the Precision Oscillator connected in place of R1 is the Precision Oscillator's return loss.

8. Remove R1 and S1 from impedance bridge test set-up and connect Precision Oscillator output as shown in Figure 6—2.

9. Note the VOM indication in step 8. This is the Precision Oscillator's return loss at 1000 Hz.

10. Set TTS 44 to 10,000 Hz at 0 dBm.

11. Note VOM indication in step 10. This is the Precision Oscillator's return loss at 10,000 Hz.

12. Adjust R65 on Analog Board as required to obtain equal return loss measurements (±1 dB) at 1000.0 Hz. and 10,000.0 Hz. Loss should be greater than —30 dBm at both frequencies.

13. Check return loss at 100 Hz. It should be greater than —30 dBm.

6.15 TONE RECEIVER OUTPUT POWER CALIBRATION

1. Connect test set-up as shown in Figure 6—3.

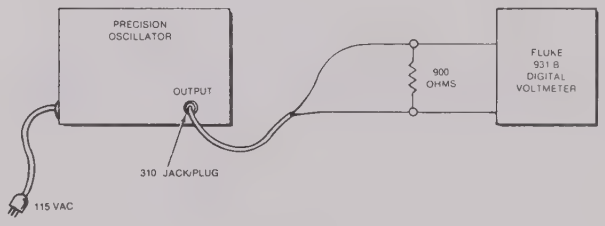

Figure 6—3. Tone Receiver Output Power Test Set-Up

2. Turn-on test equipment and oscillator.

3. Place 600Ω/TONE RCVR TEST switch to TONE RCVR TEST position.

4. Preset OUTPUT LEVEL switches to 00.0 dBm.

5. Preset FREQUENCY switches to 1000.0 Hz.

6. If necessary, adjust OVERALL LEVEL control R76 on Analog Board to obtain 0.77459 volts r.m.s. (±0.1%) on Digital Voltmeter.

7. Turn-off oscillator and test equipment.

6.16 GENERAL PURPOSE 600Ω OUTPUT POWER CALIBRATION

1. Connect test equipment as shown in Figure 6—4.

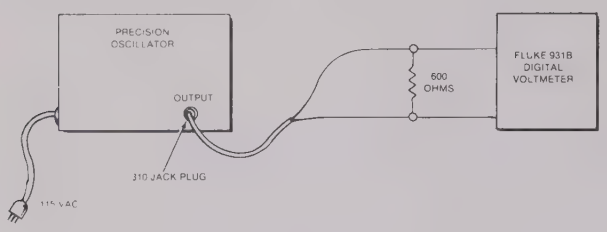

Figure 6—4. General Purpose Output Power Test Set-Up

2. Turn-on test equipment and oscillator.

3. Place 600Ω/TONE RCVR TEST switch to 600Ω position.

4. Preset OUTPUT LEVEL switches to 00.0 dBm.

5. Preset FREQUENCY switches to 1000.0 Hz.

6. If necessary, adjust 600 OHM GAIN control R62 on Analog Board to obtain 0.77459 volts r.m.s. (±0.1%) on Digital Voltmeter.

7. Turn-off oscillator and test equipment.

6.17 OVERLOAD CIRCUIT CALIBRATION

1. Connect test equipment as shown in Figure 6—5.

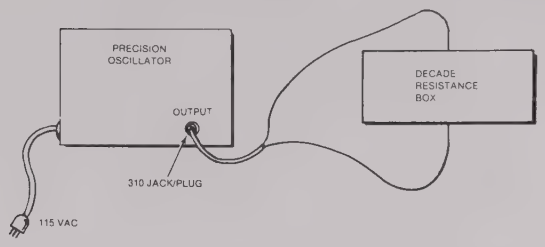

Figure 6—5. Overload Circuit Calibration Test Set-Up

2. Turn-on oscillator.

3. Place 600Ω/TONE RCVR TEST switch to TONE RCVR TEST position.

4. Set resistance decade box to 700 ohms.

5. Preset OUTPUT LEVEL switches to +9.9 dBm.

6. Preset FREQUENCY switches to 1000.0 Hz.

7. If necessary, adjust OFFSET control R77 on Analog Board until OVERLOAD indicator just lights.

8. Increase resistance of decade box until OVERLOAD indicator goes out. Resistance should be less than 900 ohms (nominally 750 ohms).

9. Turn-off oscillator and replace bottom cover.

SECTION 7

DIAGRAMS

7.1 This section contains functional, interconnection, schematic and parts location diagrams for the Precision Oscillator.

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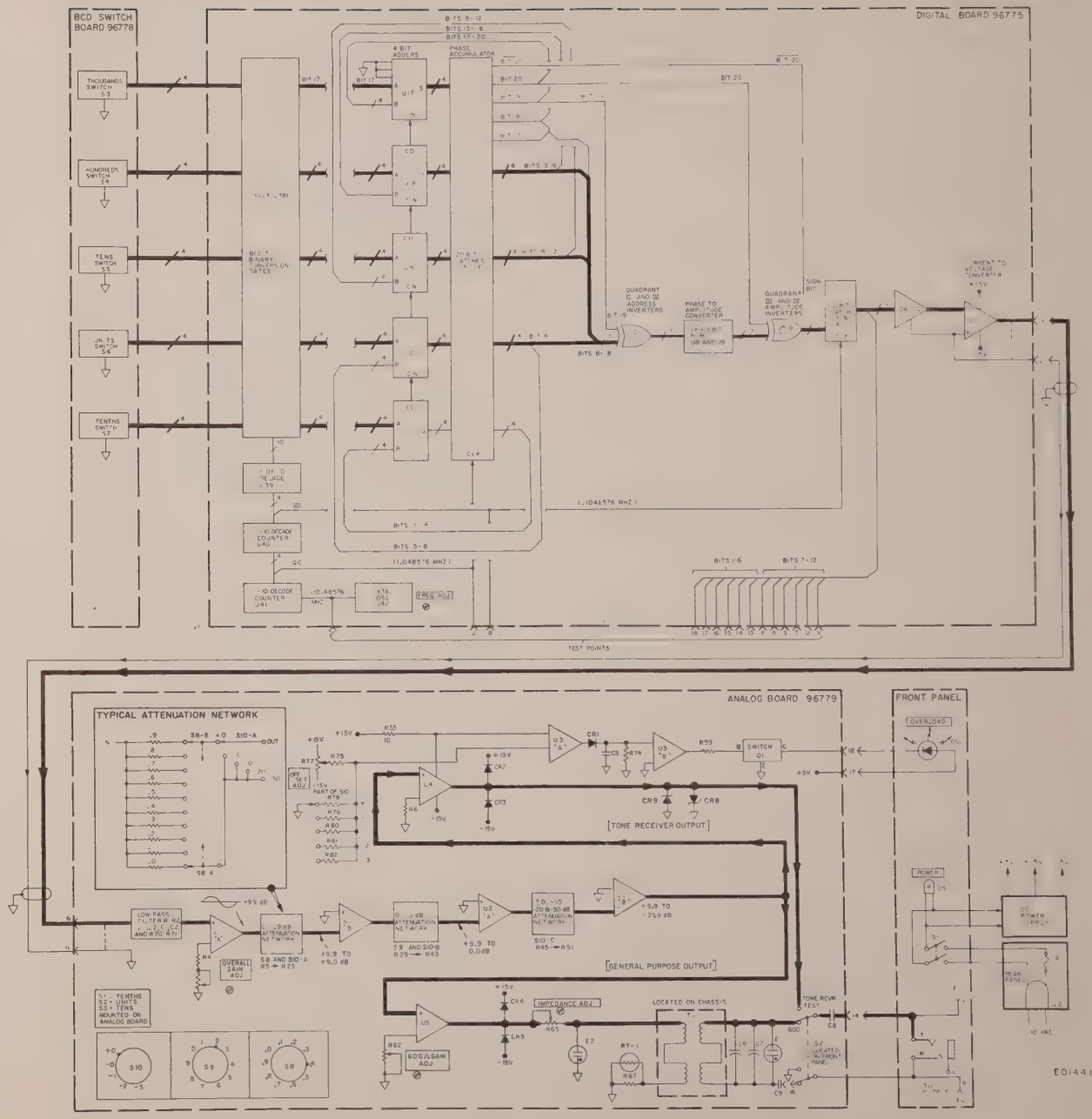
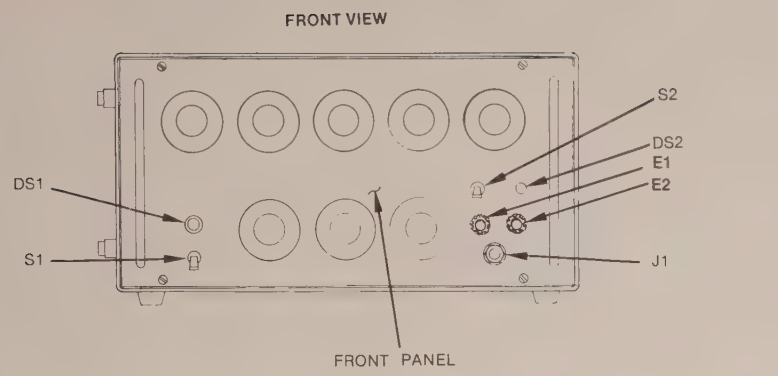
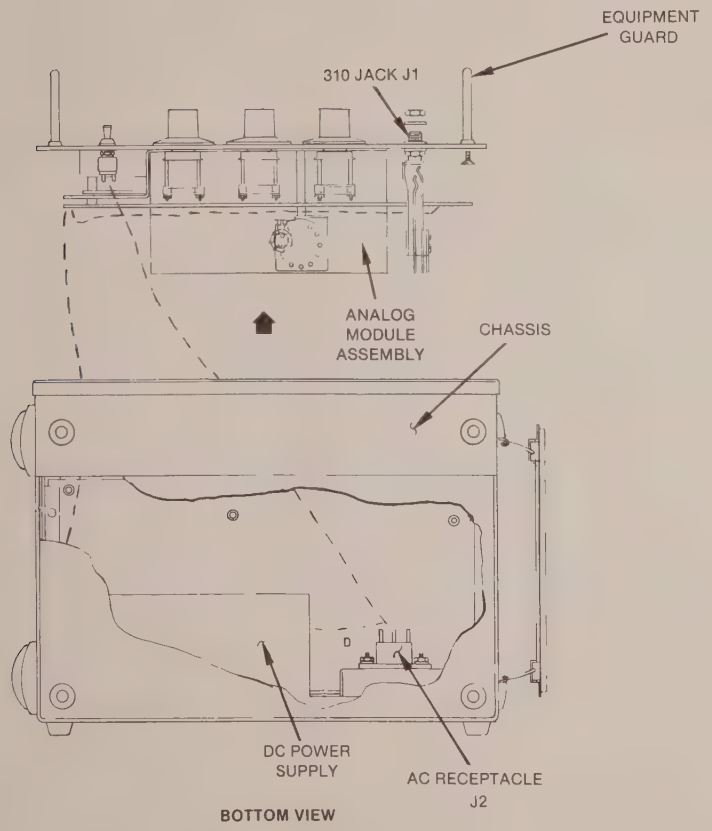


Figure 7—1. Functional Schematic Diagram





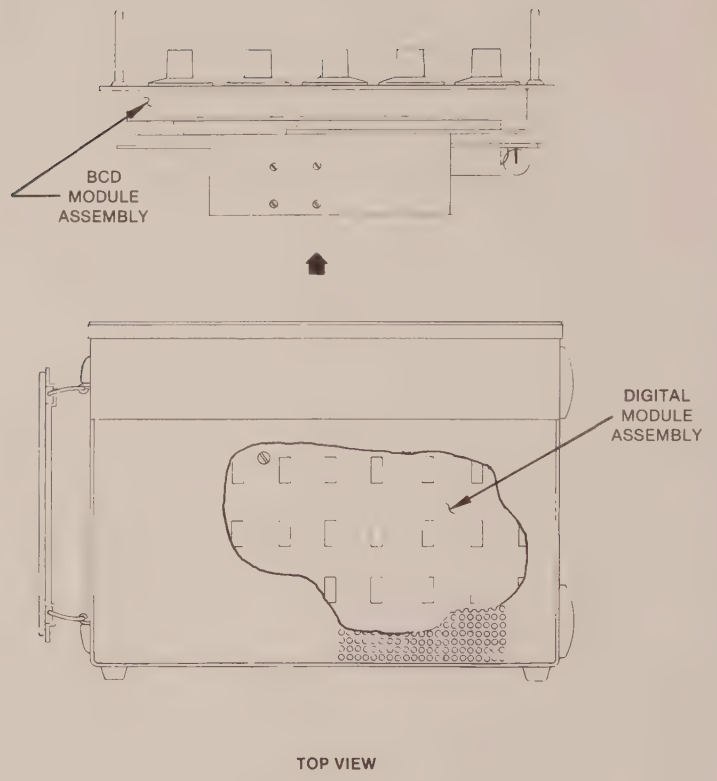
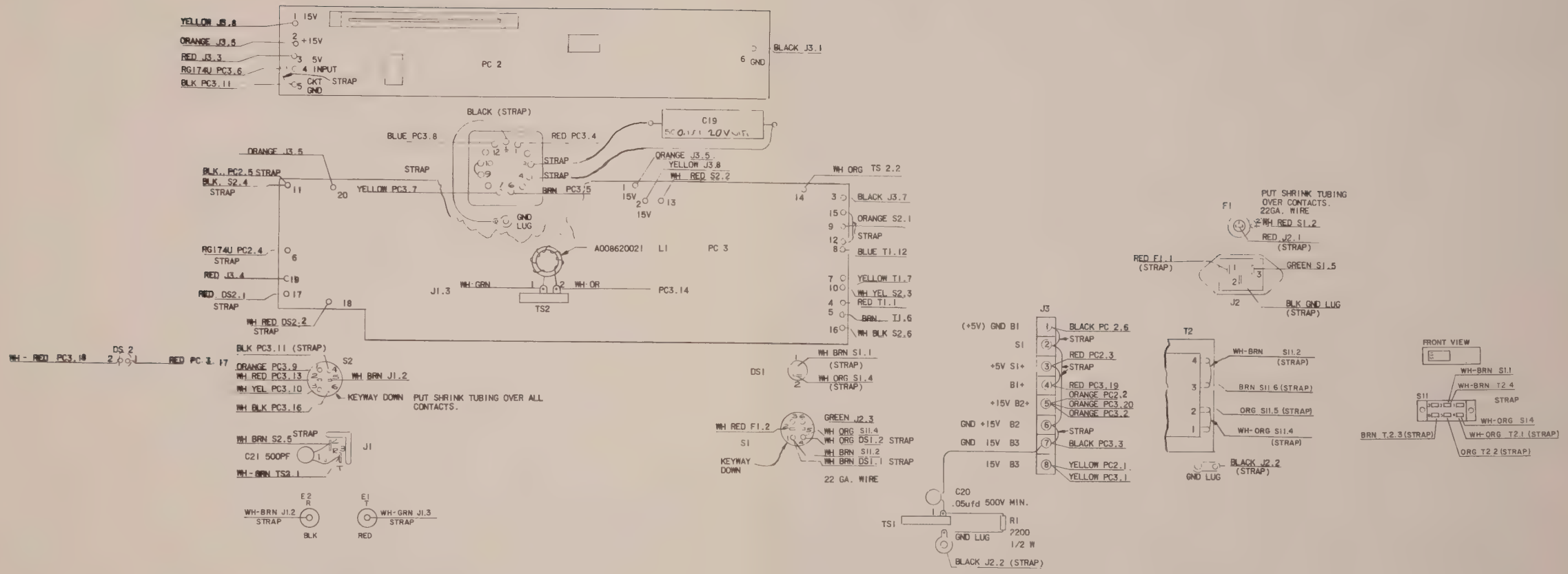


Figure 7—2. Overall Assembly Parts Location Diagram



2. USE INSULATED SHOULDER WASHERS ON J1 (310 JACK).

1. SOLDER JOINTS ON FUSE HOLDER AND AC RECEPTACLE TO BE COVERED WITH SHRINK TUBING AFTER WIRING.

NOTES

Figure 7—3. Overall Wiring Diagram

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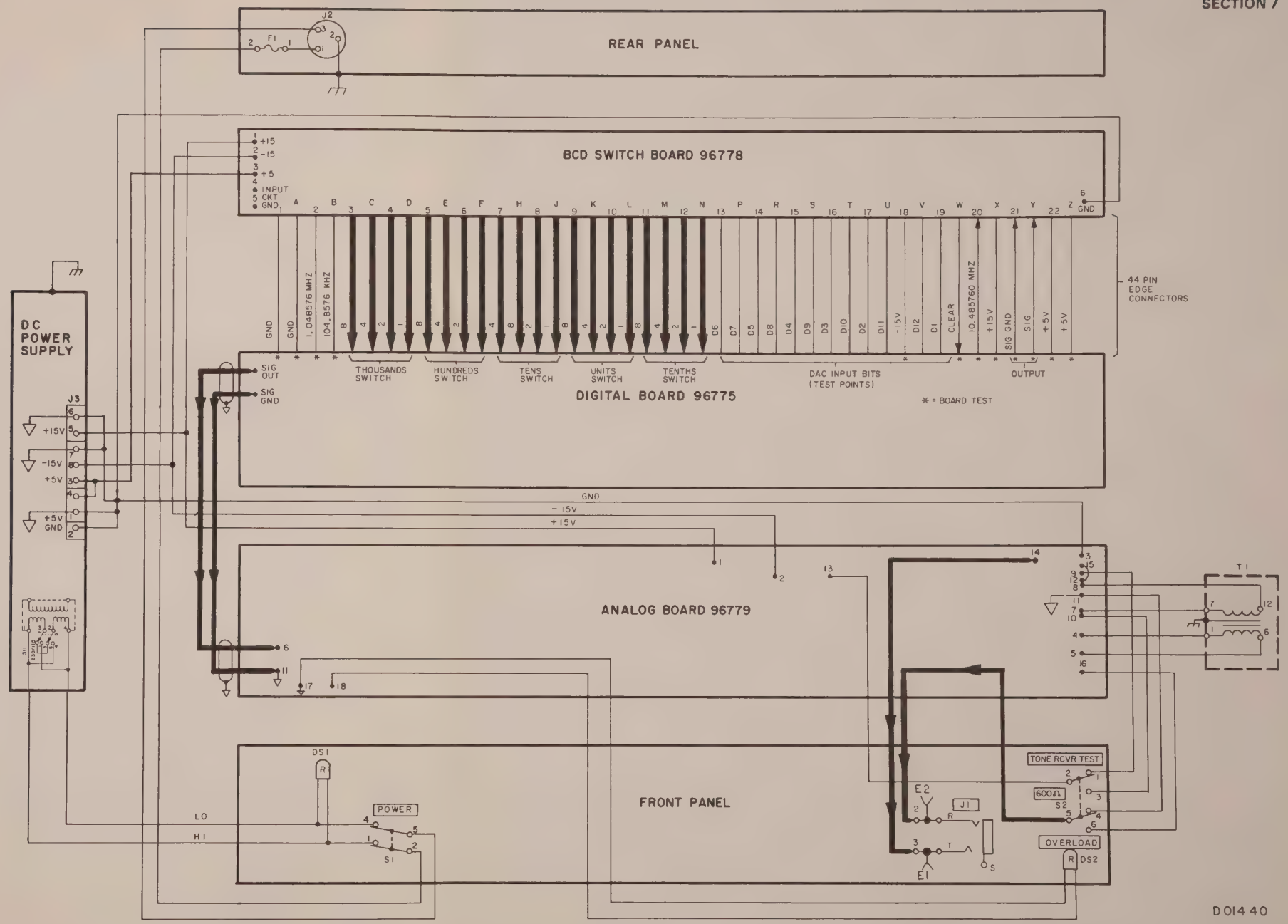

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Figure 7—4. Overall Assembly Interconnection Diagram

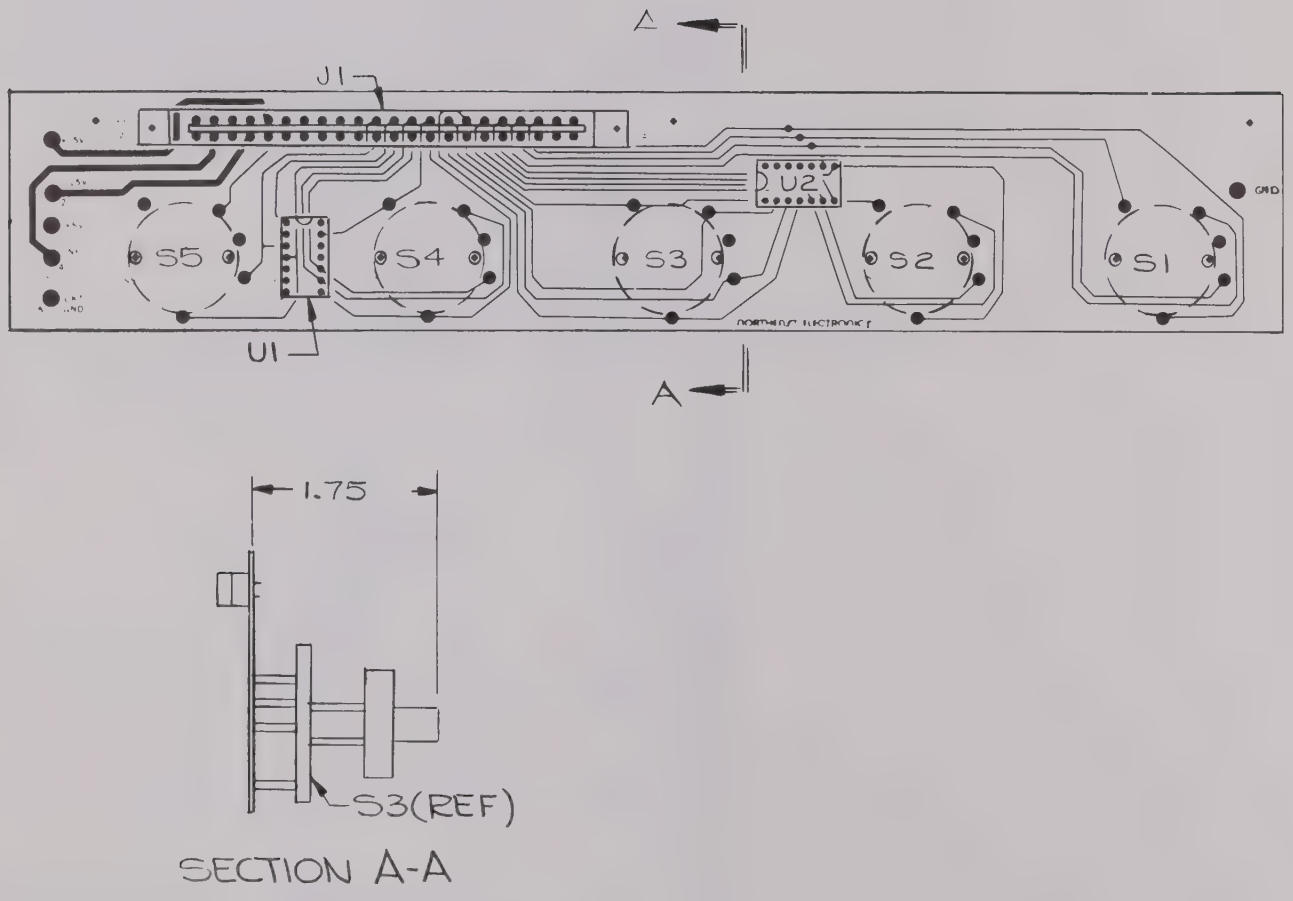
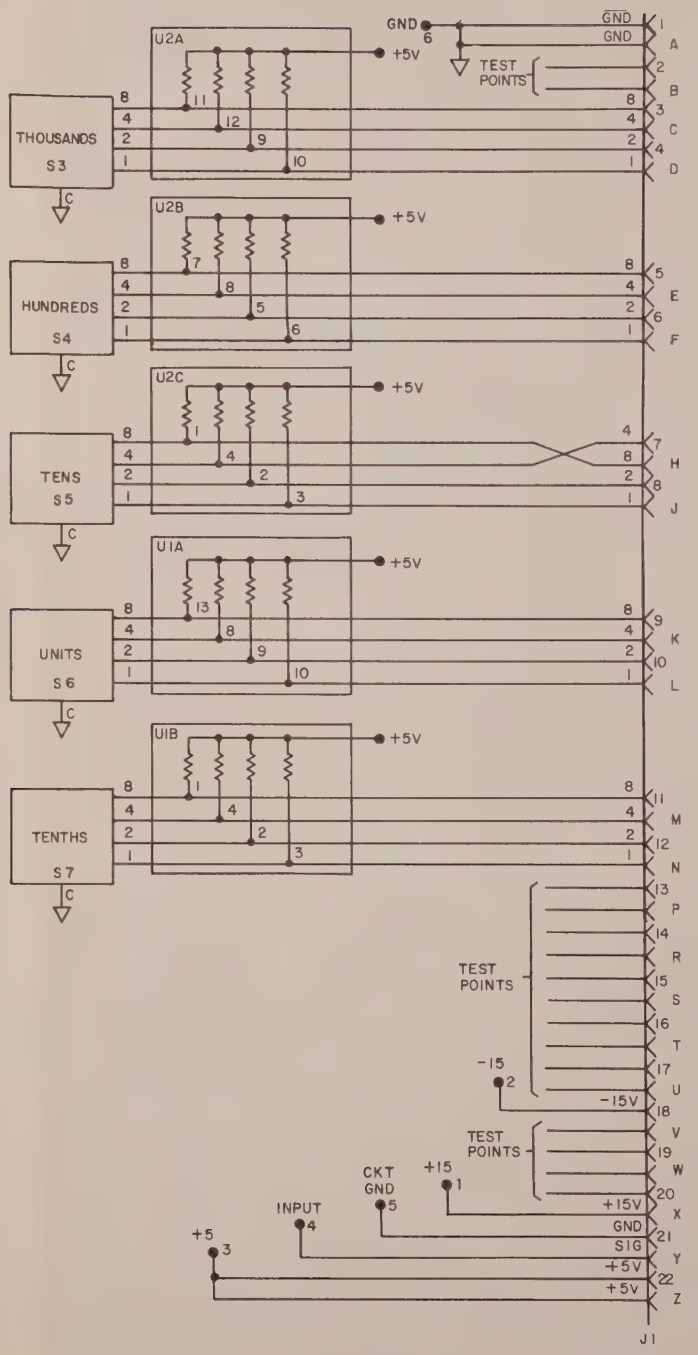


Figure 7—5. BCD Switch Board 96778 Parts Location Diagram



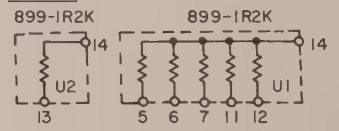
NOTES:

1. ALL RESISTORS ARE 2K OHMS, 1/4 WATT, ± 10%.
2. TEST POINTS PROVIDE ACCESS TO DIGITAL BOARD. 96775 WHEN PLUGGED INTO BCD SWITCH BOARD.

I C	TYPE	+5V
U1, U2	BECKMAN 899-1-R2K	14

HIGHEST REFERENCE DESIGNATIONS	
U2	S5

SPARES



C01438

NE PART NO.	1715-00-020
REF DESIG	A3
PC NO.	96778

Figure 7—6. BCD Switch Board 96778 Schematic Diagram

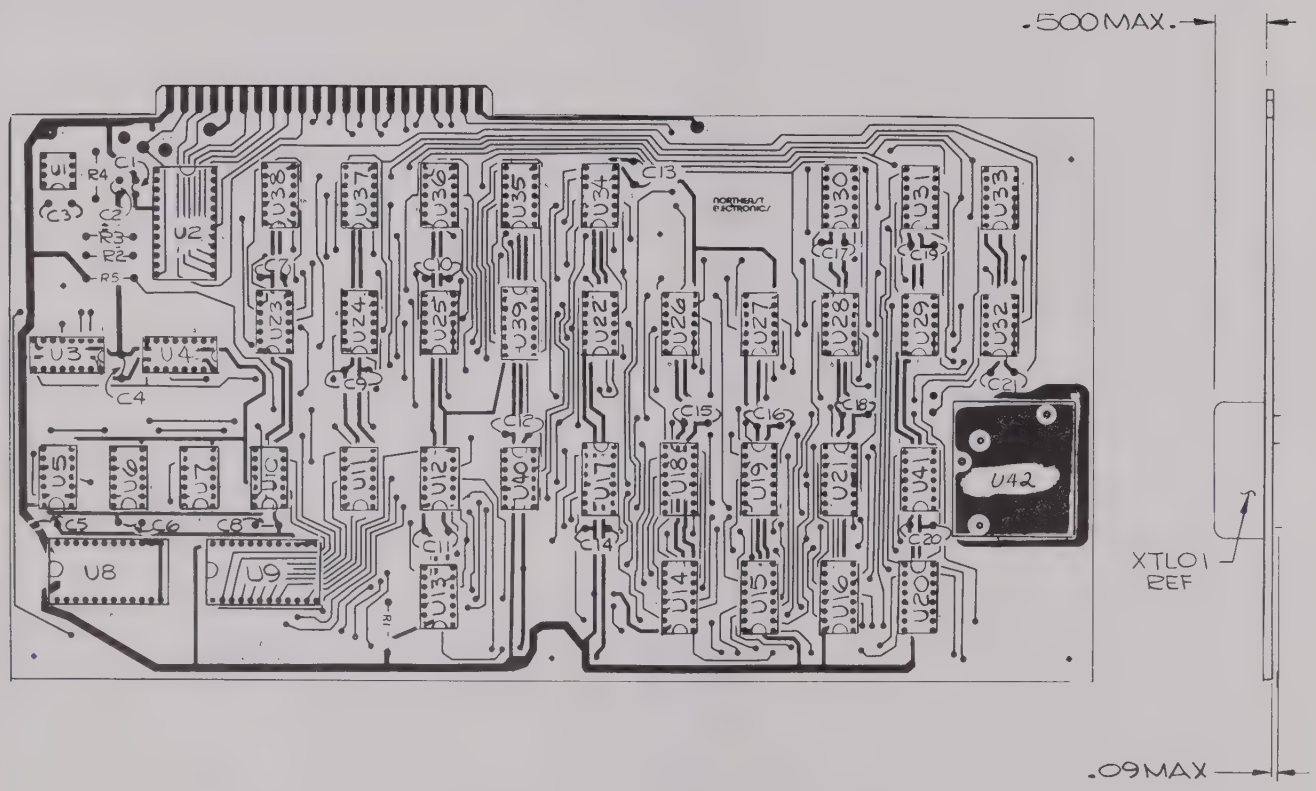
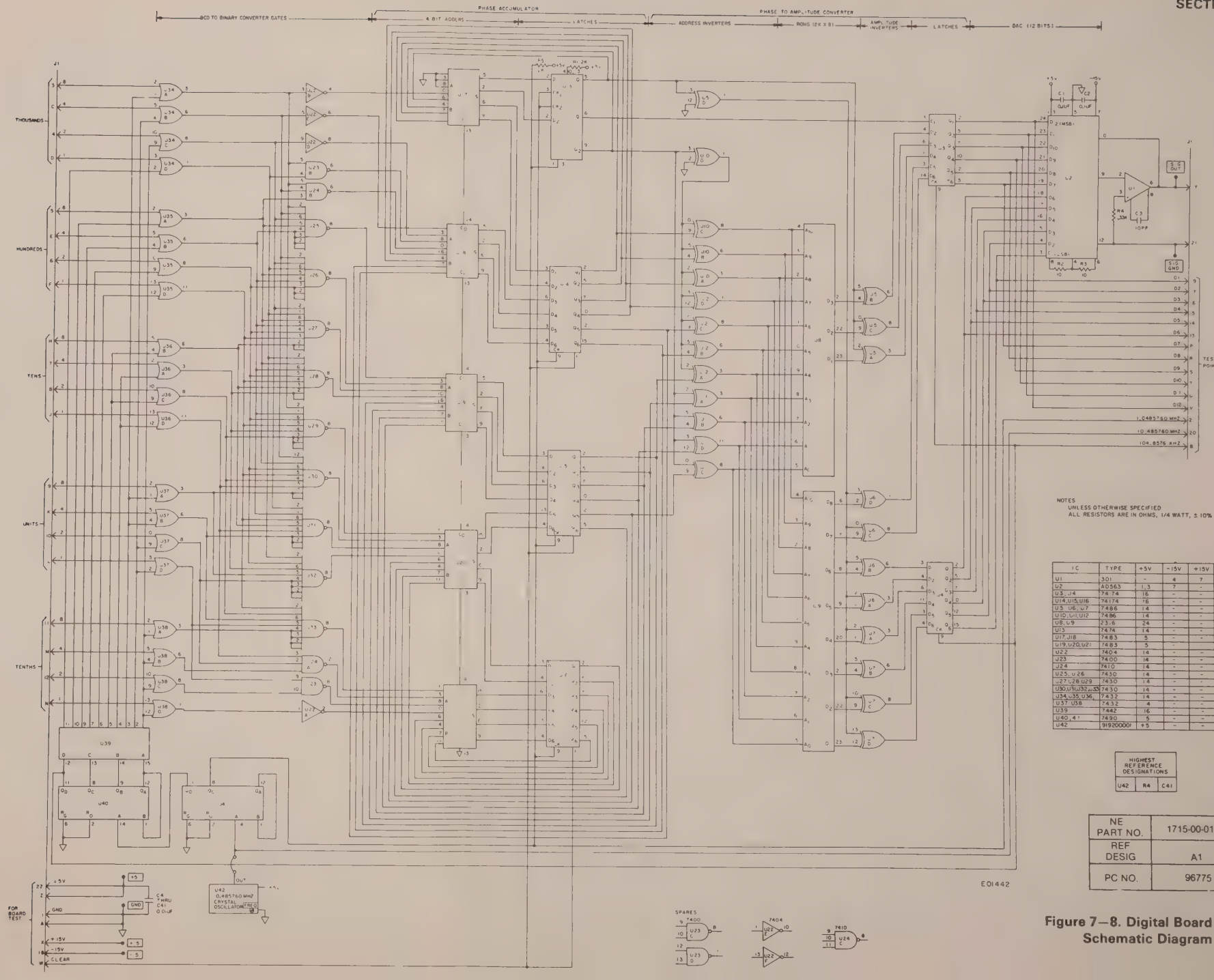


Figure 7—7. Digital Board 96775 Parts Location Diagram



IC	TYPE	+5V	-15V	+15V	GND
U1	301	-	4	7	-
U2	AD563	1,3	7	-	5
U3, U4	74174	16	-	-	8
U14, U15, U16	74174	16	-	-	8
U5, U6, U7	7486	14	-	-	7
U10, U11, U12	7486	14	-	-	7
U8, U9	2316	24	-	-	12,13,14,15
U13	7474	14	-	-	7
U17, U18	7483	5	-	-	12
U19, U20, U21	7483	5	-	-	12
U22	7404	14	-	-	7
U23	7400	14	-	-	7
U24	7410	14	-	-	7
U25, U26	7430	14	-	-	7
U27, U28, U29	7430	14	-	-	7
U30, U31, U32, U33	7430	14	-	-	7
U34, U35, U36	7432	14	-	-	7
U37 U38	7432	4	-	-	7
U39	7442	16	-	-	8
U40, 41	7490	5	-	-	10
U42	91920001	+5	-	-	GND

HIGHEST REFERENCE DESIGNATIONS		
U42	R4	C41

NE PART NO.	1715-00-016
REF DESIG	A1
PC NO.	96775

Figure 7—8. Digital Board 96775 Schematic Diagram

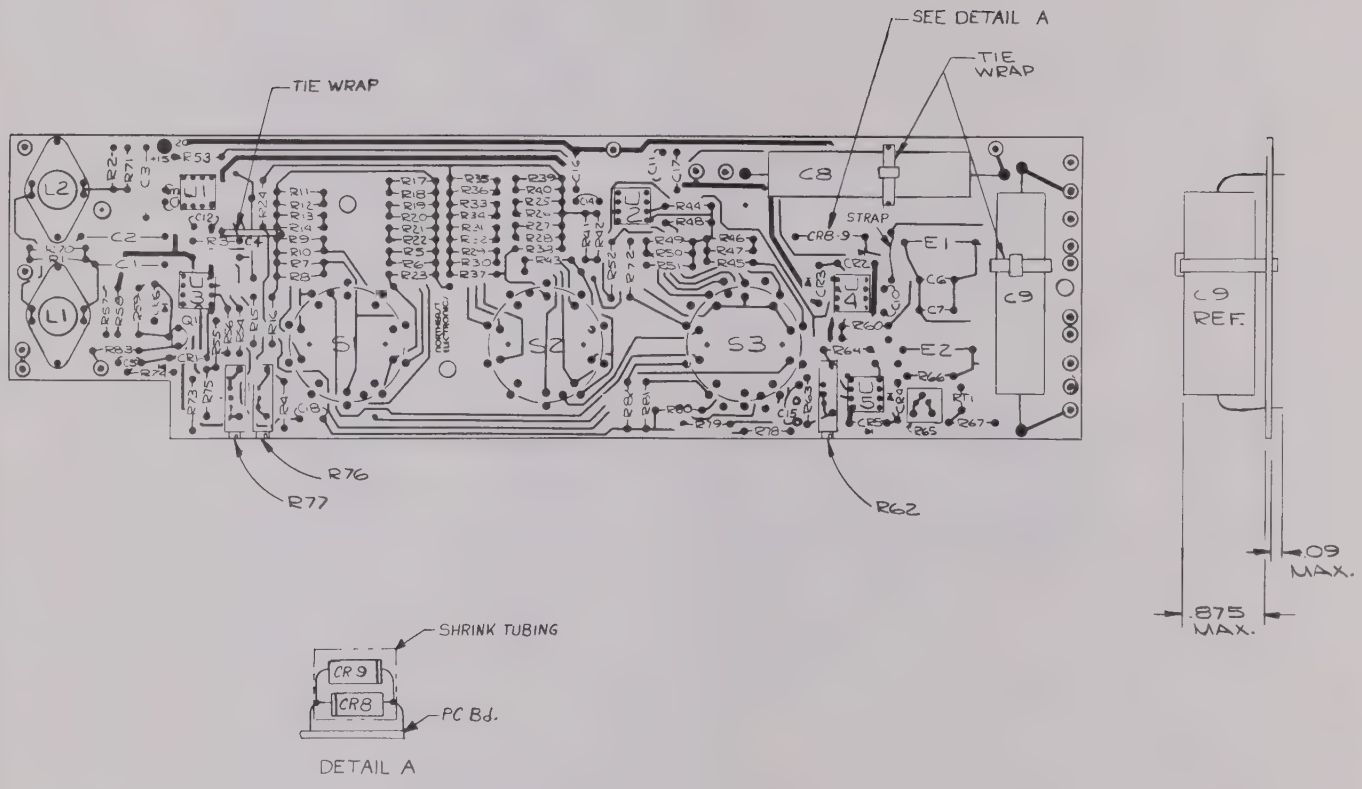
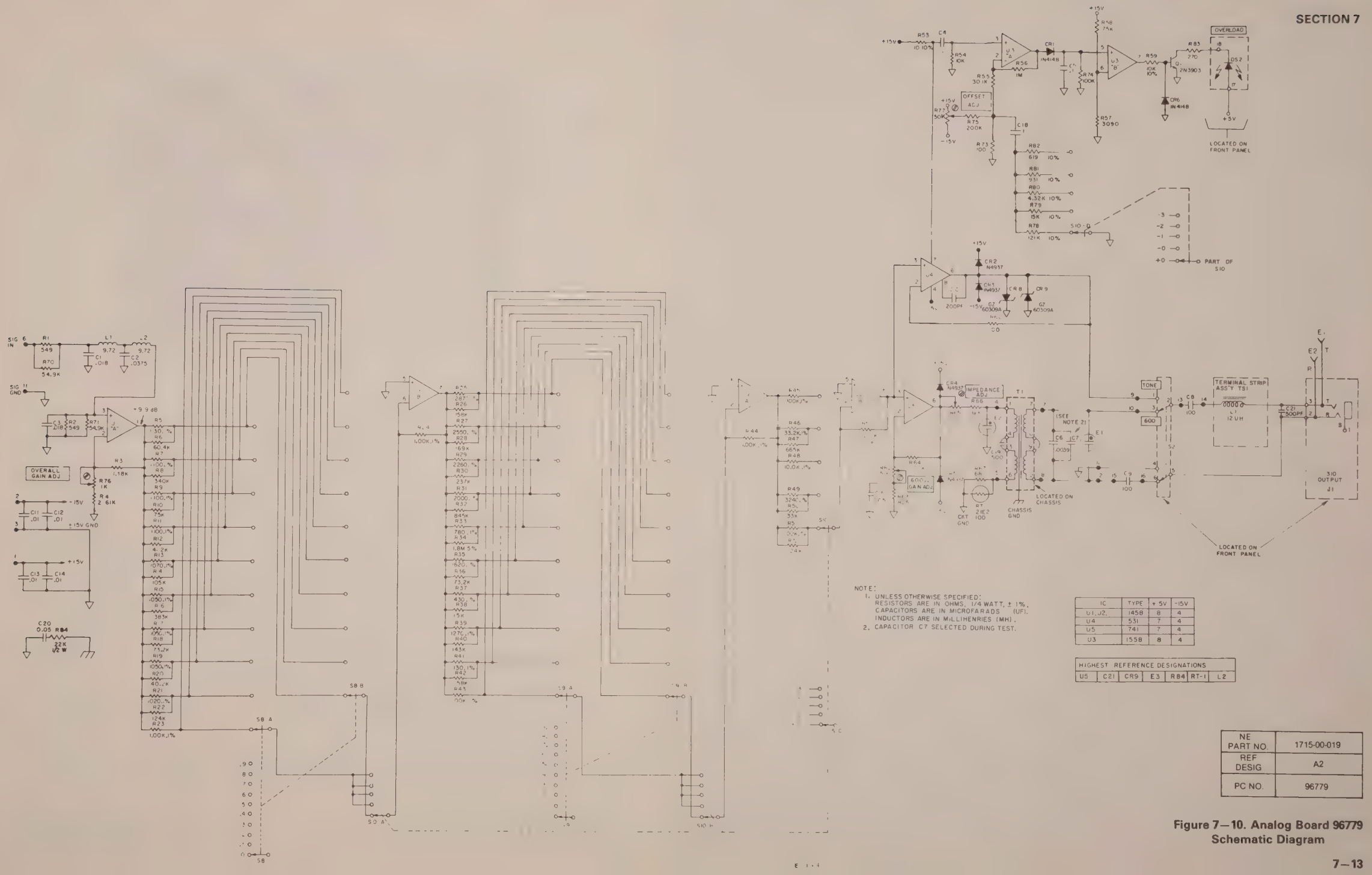


Figure 7—9. Analog Board 96779 Parts Location Diagram



NOTE:
1. UNLESS OTHERWISE SPECIFIED:
   RESISTORS ARE IN OHMS, 1/4 WATT, ± 1%.
   CAPACITORS ARE IN MICROFARADS (UF).
   INDUCTORS ARE IN MILLIHENRIES (MH).
2. CAPACITOR C7 SELECTED DURING TEST.

IC	TYPE	+5V	-15V
U1, U2,	1458	8	4
U4	531	7	4
U5	741	7	4
U3	1558	8	4

HIGHEST REFERENCE DESIGNATIONS						
U5	C21	CR9	E3	RB4	RT-1	L2

NE PART NO.	1715-00-019
REF DESIG	A2
PC NO.	96779

Figure 7—10. Analog Board 96779 Schematic Diagram

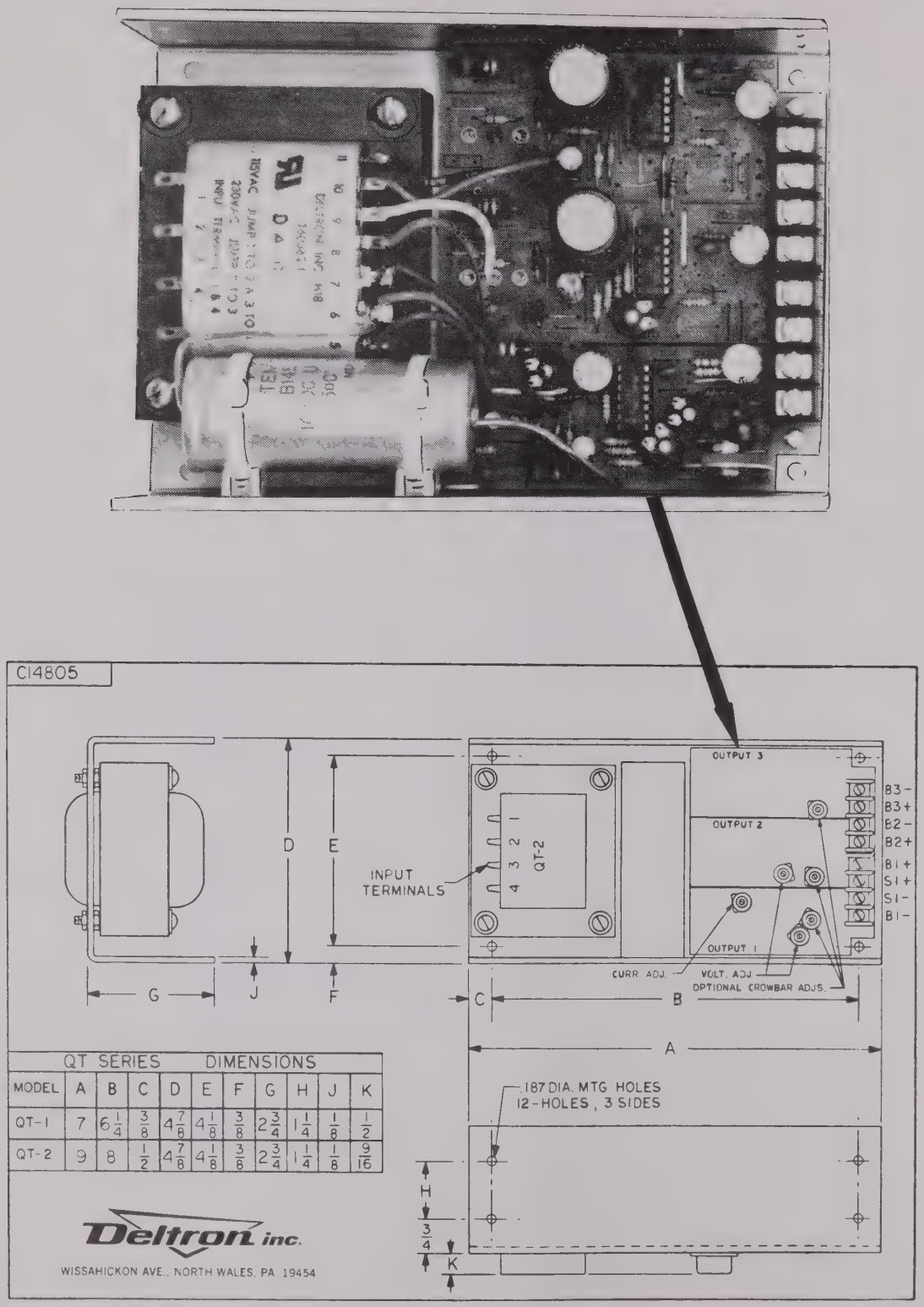
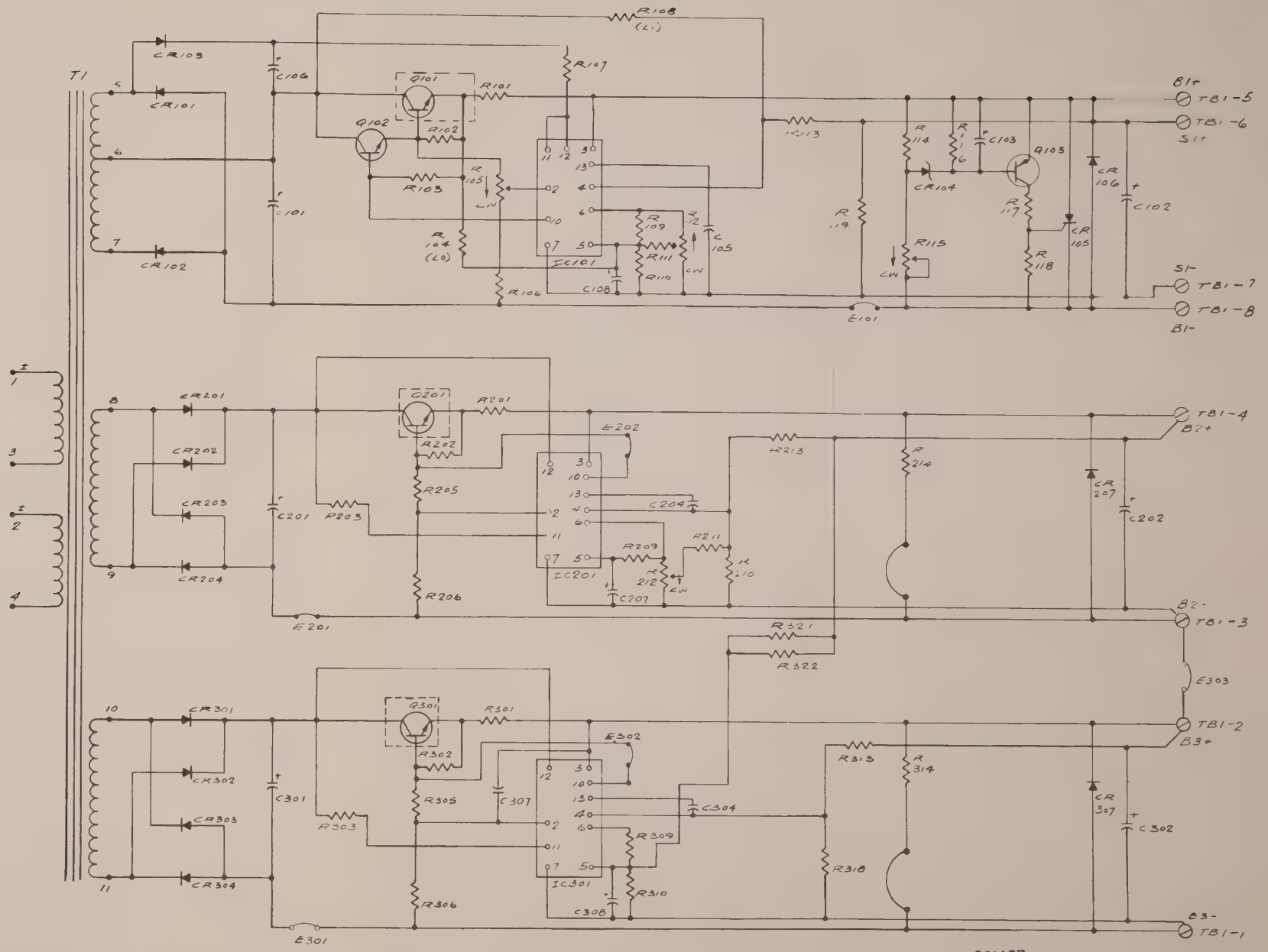


Figure 7—11. DC Power Supply Parts Location Diagram



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NOTES

1. ON CHASSIS
2. SEE PARTS LIST FOR VALUES.

Figure 7—12. DC Power Supply Schematic Diagram

SECTION 8

PARTS LISTS

8.1 This section contains parts lists for the Precision Oscillator.

Table 8—1. Overall Assembly Parts List (171501001)

REFERENCE DESIGNATOR	DESCRIPTION VALUE	POWER	TOL	VOLTS	MFGR.	MFGR. PART NO.	N.E.C. PART NO.
A1	PC BD 96775 DIGITAL ASSY						A171500016
A2	BCD MODULE ASSY						A171500020
A3	ANALOG MODULE ASSY						A171500019
A4	DC POWER SUPPLY				DELTRON	14805	960104005
C20	.05UF		20%	500V	SPRAGUE	5GA-S50	330405031
C21	500PF		10%	1KV	CRL	DD-501	330005010
DS-1	T-2	1/15W		105V	CHICAGO	NE2-D	730000700
DS-2		10 MA			H.PACKARD	5082-4658	564500801
E1	BINDING POST—RED				H.H. SMITH	1517-102	652400002
E2	BINDING POST—BLK				H.H. SMITH	1517-103	652400001
F1	FUSE	1A		250V	BUSSMAN	MDL	863101400
J1	MT332B				SWCRFT	5J-1583	650403100
J2	3-PIN	6A		250V	BELDEN	17252	652201700
R1	2.2K	1/2W	10%		AB	TYPE EB	200202226
S1-2	DPDT				AMERICAN	ST2-1F1	620400001
S11	DPDT	3A		125V	SWCRFT	46206LF	645500200
XF1	FUSE HOLDER				BUSSMAN	BUSS HTA	863300010

Table 8—2. Digital Module Assembly Parts List (171500016)

REFERENCE DESIGNATOR	DESCRIPTION VALUE	POWER	TOL	VOLTS	MFGR.	MFGR. PART NO.	N.E.C. PART NO.
C1-2	.1UF	Y5V TC	20%	50V	ERIE	8121-050-651-104M	330801040
C3	10PF	S2LTC	10%	1KV	CENTRALAB	DD-100	330001000
C4-21	.01UF		20%	16V	CENTRALAB	UK16-103	330701031
R1	2K	1/4W	5%		AB	TYPE CB	200102025
R2-3	10-	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220210091
R4	1330-	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220213311
R5	2K	1/4W	5%		AB	TYPE CB	200102025
U1	8PDIL	500MW			NAT. SEMI	LM301AN	500003010
U2	24DIP				ANALOG DEV	AD563JD/BIN	510100210
U3-4	16DIP-P			TTL	TI	SN74174N	510074174
U5-7	14DIP-P			TTL	TI	SN7486N	510074860
U8	PROGRAMED ROM, #2				SYNERTEK	27009	514000102
U9	PROGRAMED ROM, #1				SYNERTEK	27008	514000101
U10-12	14DIP-P			TTL	TI	SN7486N	510074860
U13	14DIP-P			TTL	TI	SN7474N	510074740
U14-16	16DIP-P			TTL	TI	SN74174N	510074174
U17-21	14DIP-P			TTL	TI	SN7483N	510074830
U22	14DIP-P			TTL	TI	SN7404N	510074040
U23	14DIP-P			TTL	TI	SN7400N	510074000
U24	14DIP-P			TTL	TI	SN7410N	510074100
U25-33	14DIP-P			TTL	TI	SN7430N	510074300
U34-38	14DIP-P			TTL	TI	SN7432N	510074320
U39	16DIP-P			TTL	TI	SN7442N	510074420
U40-41	14DIP-P			TTL	TI	SN7490AN	510074900
U42	OSCILLATOR,10.485760				VECTRON	CO-231T-5Y	919200001

Table 8—3. Analog Module Assembly Parts List (171500019)

REFERENCE DESIGNATOR	DESCRIPTION VALUE	POWER	TOL	VOLTS	MFGR.	MFGR. PART NO.	N.E.C. PART NO.
C19	500 UF			20E	TSI	PA500MT20NP	301305071
L1	INDUCTOR ASSY						A008620023
PC3	PC BD 9E779 ANALOG ASSY						A171500018
S8-9	SWITCH,ROTARY				OAK	5-16E91-427	625102701
S10	SWITCH,ROTARY				OAK	5-21791-411	625102702
T-1	P50 TO 600 S50K SPLIT				NESHAMINY	AF-672	400200100
TS2	TERM STRIP 3POS HORIZ				HH SMITH	853	850900200

Table 8—4. Analog Board Parts List (171500018)

REFERENCE DESIGNATOR	DESCRIPTION VALUE	POWER	TOL	VOLTS	MFGR.	MFGR. PART NO.	N.E.C. PART NO.
C1	.018UF		1%	100V	F-DYNE	PPA11-.018-150-1	322401830
C2	.0375UF		1%	100V	F-DYNE	PPA11-.0375-100-1	322437520
C3	.018UF		1%	100V	F-DYNE	PPA11-.018-150-1	322401830
C4	1UF		10%	100V	SPRAGUE	225P10591YD3	320001050
C5	.1UF	Y5V TC	20%	50V	ERIE	8121-050-651-104M	330801040
C6	.0039UF		10%	100V	SPRAGUE	225P39291WD3	320003920
C7	SELVAL		10%		SPRAGUE	225P	320000000
C8-9	100UF			150V	TSI	PA100PV150NP	301301072
C10	200PF	S3NTC	10%	1KV	CENTRALAB	DD-201	330002010
C11-14	.01UF		20%	16V	CENTRALAB	UK16-103	330701031
C15	.005UF		10%	100V	SPRAGUE	225P50291WD3	320005020
C16-18	1UF	Z5U TC	20%	50V	SPRAGUE	5C023105X0500C5	330501050
CR1	D035 4NS 10MA		SI	50UA	FAIRCHILD	1N4148	560041480
CR2-5	A1 200NS 1A		SI	.1MA	MOTOROLA	1N4937	560049370
CR6	D035 4NS 10MA		SI	50UA	FAIRCHILD	1N4148	560041480
CR8-9	BV 7.35V		5%		GEN SEMI	GZ60309A	565500003
E1-2	PROTECTOR S/V GAS				SIEMENS	B1-C90/20	566009020
L1-2	9.3 MH		1%		ARTTED	AC9317	455100108
Q1	TO-92 350MW TA NPN			40V	MOTOROLA	2N3903	550039030
R1-2	54.9K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220254921
R3	1.18K	1/8W	1%		ELECTRA	RN55 SIZE 25 PPM	221011811
R4	2.61K	1/8W	1%		VPR	RN55 SIZE 25 PPM	221026111
R5	1.13K	1/8W	.1%		ELECTRA	RN55 SIZE 25 PPM	221011319
R6	60.4K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220260421
R7	1.1K	1/8W	.1%		VPR	RN55 SIZE 25 PPM	221011019
R8	340K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220234031
R9	1.1K	1/8W	.1%		VPR	RN55 SIZE 25 PPM	221011019
R10	75K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220275021
R11	1.1K	1/8W	.1%		VPR	RN55 SIZE 25 PPM	221011019
R12	41.2K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220241221
R13	1.07K	1/8W	.1%		ELECTRA	RN55 SIZE 25 PPM	221010719
R14	105K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220210531
R15	1.05K	1/8W	.1%		ELECTRA	RN55 SIZE 25 PPM	221010519
R16	383K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220238331
R17	1.05K	1/8W	.1%		ELECTRA	RN55 SIZE 25 PPM	221010519
R18	73.2K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220273221

Table 8—4. (cont'd)

REFERENCE DESIGNATOR	DESCRIPTION VALUE	POWER	TOL	VOLTS	MFGR.	MFGR. PART NO.	N.E.C. PART NO.
R19	1.05K	1/8W	.1%		ELECTRA	RN55 SIZE 25 PPM	221010519
R20	40.2K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220240221
R21	1.02K	1/8W	.1%		ELECTRA	RN55 SIZE 25 PPM	221010219
R22	124K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220212431
R23-24	1K	1/8W	.1%		VPR	RN55 SIZE 25 PPM	221010019
R25	2.87K	1/8W	.1%		ELECTRA	RN55 SIZE 25 PPM	221028719
R26	158K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220215831
R27	2.55K	1/8W	.1%		ELECTRA	RN55 SIZE 25 PPM	221025519
R28	169K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220216931
R29	2.26K	1/8W	.1%		ELECTRA	RN55 SIZE 25 PPM	221022619
R30	237K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220223731
R31	2K	1/8W	.1%		ELECTRA	RN55 SIZE 25 PPM	221020019
R32	845K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220284531
R33	1.78K	1/8W	.1%		ELECTRA	RN55 SIZE 25 PPM	221017819
R34	1.8M	1/4W	10%		AB	TYPE CB	200101856
R35	1.62K	1/8W	.1%		ELECTRA	RN55 SIZE 25 PPM	221016219
R36	73.2K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220273221
R37	1.43K	1/8W	.1%		ELECTRA	RN55 SIZE 25 PPM	221014319
R38	115K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220211531
R39	1.27K	1/8W	.1%		ELECTRA	RN55 SIZE 25 PPM	221012719
R40	143K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220214331
R41	1.13K	1/8W	.1%		ELECTRA	RN55 SIZE 25 PPM	221011319
R42	158K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220215831
R43-44	1K	1/8W	.1%		VPR	RN55 SIZE 25 PPM	221010019
R45	100K	1/8W	.1%		VPR	RN55 SIZE 25 PPM	221010039
R46	33.2K	1/8W	.1%		ELECTRA	RN55 SIZE 25 PPM	221033229
R47	665K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220266531
R48	10K	1/8W	.1%		ELECTRA	RN55 SIZE 25 PPM	221010029
R49	3.24K	1/8W	.1%		ELECTRA	RN55 SIZE 25 PPM	221032419
R50	133K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220213331
R51	1.02K	1/8W	.1%		ELECTRA	RN55 SIZE 25 PPM	221010219
R52	1K	1/8W	.1%		VPR	RN55 SIZE 25 PPM	221010019
R53	10-	1/4W	10%		AB	TYPE CB	200101006
R54	10K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220210021
R55	30.1K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220230121
R56	1M	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220210041
R57	3090-	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220230911
R58	75K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220275021
R59	10K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220210021
R60	100-	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220210001
R62	500-	.75W	10		HELIPOT	89PR500	232505010
R63	825-	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220282501
R64	1K	1/8W	.1%		VPR	RN55 SIZE 25 PPM	221010019
R65	100-	1/2W	10%	200V	HELIPOT	72PMR100	232701010
R66	365-	1/8W	1%		VARIOUS	RN55C3650F	222036501
R67	68.1-	1/8W	1%		ELECTRA	RN55 SIZE 50 PPM	222068191
R70-71	549-	1/8W	1%		ELECTRA	RN55 SIZE 25 PPM	221054991
R72	124K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220212431
R73	100-	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220210001
R74	100K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220210031
R75	200K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220220031
R76	1K	.75W	10%		HELIPOT	89PR1K	232501020
R77	50K	.75W	10		HELIPOT	89PR50K	232505030
R78	121K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220212131
R79	15K	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220215021
R80	4320-	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220243211
R81	931-	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220293101
R82	619-	1/8W	1%		ELECTRA	RN55 SIZE 100 PPM	220261901
R83	270-	1/4W	10%		AB	TYPE CB	200102716
RT-1	100	@	25		VECO	21E2	290101010

Table 8—4. (cont'd)

REFERENCE DESIGNATOR	DESCRIPTION VALUE	POWER	TOL	VOLTS	MFGR.	MFGR. PART NO.	N.E.C. PART NO.
U1-2	8PD1L	80MW		18OV	NAT.SEMI	LM1458N	500001458
U3	8 DIP				SIGNETICS	MC1558V	500001558
U4	8PDIL			22V	SIGNETICS	NE531	500005310
U5	8PDIL				NAT. SEMI	LM741CN	500007412

Table 8—5. BCD Module Assembly Parts List (171500020)

REFERENCE DESIGNATOR	DESCRIPTION VALUE	POWER	TOL	VOLTS	MFGR.	MFGR. PART NO.	N.E.C. PART NO.
PC2	PC BD 96778 SWITCH ASSY						A171500017
S3-7	SWITCH,ROTARY				OAK	5-12381-434	625102700

Table 8—6. DC Power Supply Parts List (960104005)

REFERENCE DESIGNATION	DESCRIPTION VALUE	POWER	TOL	VOLT	MFGR	PART NUMBER
C101	10,000 UF		10%	16	DELTRON	14595
C102	470 UF		10%	10	ILLINOIS ELNA	14595
C103	1 UF		20%	25	HITACHI	14595
C105	.001 UF		10%	500	DELTRON	14159
C106,C302, C202	100 UF		10%	16	ILLINOIS ELNA	14159
C108,C207, C308	5 UF		10%	35	ILLINOIS ELNA	14159
C201,C301	2200 UF		10%	35	NIPPON	14159
C204,C304	100 PF		10%	500	DELTRON	14159
C307	SEL VAL		—	—	HITACHI	14159
CR101,CR102 CR207,CR307	RECTIFIER		—	—	— — —	1N5400
CR103,CR106, CR201-CR204 CR301-CR304	RECTIFIER		—	—	GENERAL INSTRUMENT	M1006
CR104	ZENER DIODE		—	—	— —	1N752A
CR105	SCR		—	—	— —	2N4441
E101	LINK, #32 AWG		—	—	— —	— —
E201,E301	LINK, #34 AWG		—	—	— —	— —
E202,E302, E303	LINK, #22 AWG		—	—	— —	— —
IC101,IC201, IC301	INTEGRATED CIRCUIT		—	—	DELTRON	MC1723GL
Q101,Q201, Q301	TRANSISTOR		—	—	SOLITRON	SDT9309
Q102	TRANSISTOR		—	—	— —	2N6290
Q103	TRANSISTOR		—	—	— —	2N4356
R101	.15	2W	1%	—	INTERNATIONAL RESISTANCE	— —
R102,R202, R302	68	¼W	5%	—	SHIGMA Inc.	— —

Table 8—6. (Cont'd)

REFERENCE DESIGNATION	DESCRIPTION VALUE	POWER	TOL	VOLT	MFGR	PART NUMBER
R103	330	¼ W	5%	—	SHIGMA Inc.	— —
R104	SEL VAL	¼ W	5%	—	SHIGMA Inc.	— —
R105,R115	1K POT	—	—	10V	PIHER Intnl	— —
R106	3.3K	¼ W	5%	—	SHIGMA Inc	— —
R107	220	¼ W	5%	—	SHIGMA Inc	— —
R108	SEL VAL	¼ W	5%	—	SHIGMA Inc	— —
R109	3.9K	¼ W	5%	—	SHIGMA Inc	— —
R110,R111, R211,R213	12K	¼ W	5%	—	SHIGMA Inc	— —
R112,R212	2.5K POT	—	—	10V	PIHER Intnl	— —
R113	2.4K	¼ W	5%	—	SHIGMA Inc	— —
R114	510	¼ W	5%	—	SHIGMA Inc	— —
R116	560	¼ W	5%	—	SHIGMA Inc	— —
R117	120	¼ W	5%	—	SHIGMA Inc	— —
R118	1K	¼ W	5%	—	SHIGMA Inc	— —
R119	470	¼ W	5%	—	SHIGMA Inc	— —
R201,R301	1.5	2W	1%	—	INTERNATIONAL RESISTANCE	— —
R203	LINK #22 AWG		—	—	— —	— —
R205,R305	750	1 ¼ W	5%	—	SHIGMA Inc	— —
R206,R306	9.1K	¼ W	5%	—	SHIGMA Inc	— —
R209	4.7K	¼ W	5%	—	SHIGMA Inc	— —
R210	24K	¼ W	5%	—	SHIGMA Inc	— —
R214,R314	1.2K	¼ W	5%	—	SHIGMA Inc	— —
R215	LINK #22 AWG		—	—	—	— —
R303	LINK #22 AWG		—	—	— —	— —
R310,R318	6.19K	—	1%	—	CORNING ELECTRONICS	NA 55
R313	8.87K	—	1%	—	CORNING ELECTRONICS	NA55
R315	LINK #22 AWG		—	—	— —	— —
R321	24.3K	—	1%	—	CORNING ELECTRONICS	NA 55
R322	910K	¼ W	5%	—	SHIGMA Inc	— —
T1	TRANSFORMER		—	—	DELTRON	T60362
TB1	TERMINAL BOARD		—	—	VERNITRON ELEC. Co.	72504-C